UNIVERSIDADE ESTADUAL DE CAMPINAS
Faculdade de Engenharia Elétrica e de Computação

MARCELO CORREIA DOS SANTOS

MPEG-SCORM: ONTOLOGY OF INTEROPERABLE METADATA FOR MULTIMEDIA AND E-LEARNING STANDARDS INTEGRATION

MPEG-SCORM: ONTOLOGIA DE METADADOS INTEROPERÁVEIS PARA INTEGRAÇÃO DE PADRÕES MULTIMÍDIA E E-LEARNING

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Thesis presented to the Faculty of Electrical and Computer Engineering of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Electrical Engineering, in the area of Telecommunications and Telematics

Tese apresentada à Faculdade de Engenharia Elétrica e de Computação da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do título de Doutor em Engenharia Elétrica, na área de Telecomunicações e Telemática

Supervisor/*Orientador*: PROF. DR. YUZO IANO

Este exemplar corresponde à versão final Tese defendida pelo aluno Marcelo Correia dos Santos e orientada pelo prof. Dr. Yuzo Iano.

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Campinas
2017

Agência(s) de fomento e nº(s) de processo(s): CAPES
ORCID: http://orcid.org/0000-0002-6755-0440

Ficha catalográfica
Universidade Estadual de Campinas
Biblioteca da Área de Engenharia e Arquitetura
Luciana Pietrosanto Milla - CRB 8/8129

Sa59m	Santos, Marcelo Correia dos, 1978- MPEG-SCORM : ontology of interoperable metadata for multimedia and e-learning standards integration / Marcelo Correia dos Santos. – Campinas, SP : [s.n.], 2017. Orientador: Yuzo Iano. Tese (doutorado) – Universidade Estadual de Campinas, Faculdade de Engenharia Elétrica e de Computação. 1. Televisão digital. 2. E-learning. 3. Metadados. 4. MPEG (Padrão de codificação de vídeo). 5. Multimídia. I. Iano, Yuzo,1950-. II. Universidade Estadual de Campinas. Faculdade de Engenharia Elétrica e de Computação. III. Título.

Informações para Biblioteca Digital

Título em outro idioma: MPEG-SCORM : ontologia de metadados interoperáveis para integração de padrões multimídia e e-learning
Palavras-chave em inglês:
Digital television
E-learning
Metadata
MPEG (Video encoding standard)
Multimedia
Área de concentração: Telecomunicações e Telemática
Titulação: Doutor em Engenharia Elétrica
Banca examinadora:
Yuzo Iano [Orientador]
Vânia Cristina Pires Nogueira Valente
Vicente Idalberto Becerra Sablón
Rangel Arthur
Carlos Eduardo Câmara
Data de defesa: 24-02-2017
Programa de Pós-Graduação: Engenharia Elétrica

COMISSÃO JULGADORA - TESE DE DOUTORADO

Candidato: Marcelo Correia dos Santos RA: 134163

Data da Defesa: 24 de fevereiro de 2017

Título da Tese: "MPEG-SCORM: ontology of interoperable metadata for multimedia and e-learning standards integration”.

Título da Tese em português: "MPEG-SCORM: ontologia de metadados interoperáveis para integração de padrões multimídia e e-learning”.

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Profa. Dra. Vânia Cristina Pires Nogueira Valente (FAAC/UNESP)
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A ata de defesa, com as respectivas assinaturas dos membros da Comissão Julgadora, encontra-se no processo de vida acadêmica do aluno.

EPIGRAPH

"Enlightenment is man's release from his self-incurred tutelage. Tutelage is man's inability to make use of his understanding without direction from another. Self-incurred is this tutelage when its cause lies not in lack of reason but in lack of resolution and courage to use one's intelligence without being directed by another.
"Sapere aude!" – Have courage to use your own reason!
is the motto of enlightenment."

Immanuel Kant

An Answer to the Question: What Is Enlightenment?

ACKNOWLEDGEMENTS

Aos meus familiares e amigos que pacientemente compreenderam-me e contribuíram para a conclusão deste trabalho.

RESUMO

A convergência entre as mídias digitais propõe uma integração entre as TIC, focadas no domínio do multimídia (sob a responsabilidade do *Moving Picture Experts Group*, constituindo o subcomitê ISO / IEC JTC1 SC29), e as TICE, (TIC para a Educação, geridas pelo ISO / IEC JTC1 SC36), destacando-se os padrões MPEG, empregados na forma de conteúdo e metadados para o multimídia, e as TICE, aplicadas à Educação a Distância, ou e-Learning (o aprendizado eletrônico). Neste sentido, coloca-se a problemática de desenvolver uma correspondência interoperável de bases normativas, atingindo assim uma proposta inovadora na convergência entre as mídias digitais e as aplicações para e-Learning, essencialmente multimídia. Para este fim, propõe-se criar e aplicar uma ontologia de metadados interoperáveis para web, TV digital e extensões para dispositivos móveis, baseada na integração entre os padrões de metadados MPEG-21 e SCORM, empregando a linguagem XPath.

Palavras-chave: Televisão Digital, e-Learning, Metadados, MPEG-21, SCORM.

ABSTRACT

The convergence of digital media offers an integration of the ICT, focused on telecommunications and multimedia domain (under responsibility of the *Moving Picture Experts Group*, ISO/IEC JTC1 SC29), with the ICTE (the ICT for Education, managed by the ISO/IEC JTC1 SC36), highlighting the MPEG formats, featured as content and as description metadata potentially applied to the Multimedia or Digital TV and as a technology applied to e-Learning. Regarding this, it is presented the problem of developing an interoperable matching for normative bases, achieving an innovative proposal in the convergence between digital Telecommunications and applications for e-Learning, both essentially multimedia. To achieve this purpose, it is proposed to create an ontology for interoperability between educational applications in Digital TV environments and vice-versa, facilitating the creation of learning metadata based objects for Digital TV programs as well as providing multimedia video content as learning objects for Distance Education. This ontology is designed as interoperable metadata for the Web, Digital TV and e-Learning, built on the integration between MPEG-21 and SCORM metadata standards, performing as a translator between the metadata standards between both domains, by employing the XPath language.

Keywords: Digital Television, e-Learning, Metadata, MPEG-21, SCORM.

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LIST OF ACRONYMS

8-VSB: Eight Level Vestigial Sideband (North-American standard).

AAC: Advanced Audio Coding, also known as MPEG-2 Part 7 or MPEG-4 Part 3, this last one the audio standard adopted by the SBTVD.

AC: Audio Coding;

ADL: Advanced Distributed Learning.

AICC: Aviation Industry CBT Committee.

API: Application Program Interface.

ARIADNE: Alliance of Remote Instructional Authoring and Distribution Networks for Europe.

ARIB: Association of Radio Industries and Business (Japanese standard);

ASCII: American Standard Code for Information Interchange.

BC: Backward Compatible (with MPEG-1 audio format);

CAM: Content Aggregation Model (SCORM norm part).

CBT: Computer-Based Training.

COFDM: Coded Orthogonal Frequency Division Multiplexing (European, Japanese and Brazilian standards);

DASE: Digital Television Application Software Environment (North-American standard);

DID: Digital Item Declaration.

DIDL: Digital Item Declaration Language.

DOI: Digital Object Identifier.

e-Procurement: Purchase and sale of supplies, work and services over the Internet (either B2B, B2C and B2G e-commerce models) as well as other information systems and networks, such as electronic data interchange and enterprise resource planning.

EBNF: Extended Backus-Naur Form.

EPG: Electronic Program Guide;

HDTV: High Definition Television;

HTML: Hypertext Markup Language.

IANA: Internet Assigned Numbers Authority.

IEEE: Institute of Electrical and Electronics Engineers.

IETF: Internet Engineering Task Force.

Infoset: Information Set.

IPMP: Intellectual Property Management and Protection.

ISBN: International Standard Book Numbers.

ISO: International Standards Organization.

ISSN: International Standard Serial Numbers.

JPEG: Joint Photographic Experts Group.

LMS: Learn Management System.

LOM: Learning Object Metadata.

LTSC: Learning Technology Standards Committee.

MHP: Multimedia Home Platform (European standard);

MIME: Multipurpose Internet Mail Extensions (IETF RFC 2045).

MP3: MPEG-1/2 layer III (audio coding).

MPEG: Moving Picture Experts Group.

MPEG-21: ISO/IEC 21000 (all parts).

MPEG-7: ISO/IEC 15938.

OOP: Object Oriented Programming.

OWL: Ontology Web Language.

PIF: Package Interchange File.

RDF Schema: Resource Description Framework.

RFC: Request for Comments.

RTE: Run-Time Environment.

SBTVD: Brazilian System of Digital Television (Sistema Brasileiro de Televisão Digital).

SCO: Sharable Content Object.

SCORM: Sharable Content Object Reference Model.

SDTV: Standard Definition Television;

SN: Sequencing and Navigation.

SPM: Smallest Permitted Maximum.

SS: Simple Sequencing.

SVG: Scalable Vector Graphics.

T-: Television.

TCP IP: Transmission Control Protocol Internet Protocol.

UML: Unified Modeling Language.

URI: Uniform Resource Identifier (IETF RFC 3986).

URL: Uniform Resource Locator (IETF RFC 3986).

URN: Uniform Resource Name (IETF RFC 3986).

W3C: World Wide Web Consortium.

XML: Extensible Markup Language (W3C XML).

XPath: XML Path Language.

XPointer: XML Pointer Language.

XSD: XML Schema Definition.

LIST OF SYMBOLS

XPath syntax symbols used on this research:

/	root node selector
//	current node match selector
.	current node selector
..	current node parent selector
[ ]	predicate selector
@	attribute selector
( )	Element selector

LIST OF PUBLISHED ARTICLES

Components of the listing: book chapter, papers in national and international journals, papers in national and international congresses. All in the condition of being accepted for **publication**.

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1. INTRODUCTION

Given the challenges of the Information and Communication Technologies applied to Education (the ICTE), as well as the various standardization initiatives, in particular by the ISO / IEC JTC1 SC36 and SC29 committees, it constitutes a relevant engineering research problem within this time to analyze and propose solutions on as the MPEG family, by means of MPEG-4, MPEG-7 and MPEG-21 standards, could provide a normative basis for associating metadata in common multimedia audiovisual and ICTE.

The gradual switch off scheduled by the federal government, from broadcast TV broadcast analog to the digital, which is assumed to be completed in 2016, has provided in a unique way the increasing convergence between audiovisual and all ICT, thinking firstly about the multimedia and broadcast, but also including therein those applied to Education – the ICTE.

The convergence of media and networks results in a mandatory redundancy of metadata standards that allow you to manage, store, manipulate the resources and tools, both with regard to ICTE as also the more general field of multimedia ICT, like the Digital Video and Television.

As a matter of fact, ICT and ICTE are networked platforms on which circulate flows of resources or information content, as well as the users, authors, publishers and distributors. All cooperate on variable degrees, since the metadata sets (which must conform to the XML schemas) run according to the desired specifications.

ICT designed before the existence of XML already worked with metadata – they tagged data content and even the series of instructions for all digital environment.

Moreover, these metadata existent before XML were more difficultly organized in "metadata systems" and did not respond to "structured schemes" corresponding to communities of practice or use.

In this new paradigm of structured information, tools today (and even more so tomorrow) are not invented and not developed as innovations independently, because they operate and articulate specifically tailored metadata for sets of projected uses.

These metadata could in theory be fully developed at the request of a single community (for example, defense or military, as the ADL, in the United States, was always responsible for these demands in that country, which were spread to the world as international standards).

But it doesn’t work this way, because even within the design highly targeted to defense, as anthropometry, metadata and schemas are developed by global communities that share a "common good", which ensure interoperability, reuse and the code normalization, which underlie the operation of any communication system.

The standardization of metadata sets and XML projects is one of the basic paradigms of the TIC of 21st Century.

All metadata sets are, in this terms, at least minimally standardized (*i.e.* developed by the group of engineers of a company or consortium), and a step forward, better standard (*i.e.* developed by global institutions of standardization which aim to ensure compatibility of consistency and no redundancy of the global supply of tools and services).

In the case of ICTE, this standardization refers to components of platforms and networks, to processes, software, content, interfaces, control systems, storage and distribution.

The convergence of digital media offers an integration of ICT focused on telecommunications and multimedia domain (under responsibility of the Moving Picture Experts Group, ISO/IEC JTC1 SC29) and the ICTE (the

ICT for Education), managed by the ISO/IEC JTC1 SC36, highlighting the MPEG standards, employees as content and metadata to the multimedia Digital TV and the technologies applied to e-Learning.

A project on the premise of an MPEG-SCORM type metadata system aims to influence the regulatory expertise community in Telecommunications Engineering to establish a harmonization between the rules and standards of multimedia features of ICTE platforms (LMS platforms or Learning Management Systems) and Video digital (MPEG 7 and 21), notably in the Digital TV system.

Thus, proposing interoperable, reusable, referable, indexable learning objects metadata in video format, through technology employment, the basis for the development process of this new candidate standard – MPEG-21 SCORM. SCORM, acronym for Sharable Content Object Reference Model, is the prominent metadata standard for the e-Learning industry.

The fundamental hypothesis comes to express the result of the observation that the set of the family of standards MPEG will become important with the advent of Digital Television straight to the switch off of the analog broadcast, in the decade of 2010 – this, coupled with the concept of the convergence of media and, therefore, their systems of standardization of metadata.

The prospects for the project: the analysis of the difficulties of possible convergences between the MPEG standards and the standards of resources and ICTE platforms (Learning Objects and LMS platforms).

Given the emergence of these environments, we propose the hypothesis that the standardization of educational multimedia (highlighting the SCORM as emblematic case of educational metadata) and the sets of metadata to digital broadcasting (MPEG again as a representative standard of a family or larger set, involving under this project the MPEG 4, 7 and 21 formats) inevitably converge, eliminating its redundancies.

In this context of standardization and convergence the ICT and ICTE are made to converge, what comes to lead to the rapprochement of their metadata systems.

In this way, the following hypothesis becomes consistent:

The standardization committees of both the domains (JTC1 SC29[1] e JTC1 SC36[2]) have here a touching point. Secondly, this process of interoperable normalization tends to favor the heavier partner – the digital audiovisual multimedia hypermedia, not the ICTE. Therefore, it comes in favor of Digital Television.

This research has as hypothesis, therefore, the study of the current norms to make a contribution to the development of a hypothetical standard metadata – SCORM MPEG Video – integrated, creating a pattern of learning objects and functional standardized video format.

This hypothesis assumes, thus, the systematic exploitation of fields and features normalized by these two large groups of experts could expand the technical-scientific knowledge and thus enable each of these instances of normative influence evolve in its development strategy its families of norms (MPEG Group SC29, and SC36 for the ICTE) and even integrate them for a common good.

This development demands the adoption and employ of some tools to match all these learning and media objects, further to the content itself (video, still images, sound, text, hypertext, among others), and must lie within a normative frame to guarantee interoperability, reusability and referring to

[1]ISO/IEC JTC1 SC29: subcommittee that normalizes sound encoding, image and multimedia information and hypermedia.
[2]ISO/IEC JTC1 SC36: subcommittee that normalizes the technologies for communication, information and education.

the major platforms or digital environments in both fields, multimedia and e-learning.

For this purpose, it was adopted in this research the XPath language, managed by the W3C.

The software engineering to support this normalization comprehends XML, MPEG-7, MPEG-21, themes approached by the SC36. Otherwise, experts from ADL, entity which developed the SCORM standard, are engaged in SC36 subcommittee too, and already proposed to in a certain way explore the capabilities of MPEG-21 to make this idea feasible.

1.1 PREMISES

In the current historical context within television communication area, this environmental condition implies a moment of transition whose movement comes from the analog technology towards digital convergence in a digital Era.

Based on the of Master's degree research [51] previously completed as a prerequisite to the present Doctorate (defense of Dissertation in December of 2011) within the Master's program in Digital Television at UNESP, whose project of technological innovation and knowledge was focused on the research and the design of a Learning Management System for Interactive Digital TV, which was built on Ginga Middleware platform, the normalized middleware by the Brazilian Digital Television System (SBTVD).

The end result of this project consisted of a written Dissertation as well as a prototype application developed on Ginga NCL platform, which consists of a Learning Management System (LMS) for Distance Education.

By its turn, the premise of departure of this Doctoral Thesis was a research accomplished in Paris France, within the Engineering School *Télécom Sud Paris*, in particular because one of the professors researchers was a director of Master's degree of the author of this Thesis at the University of Paris, in France.

The accomplished research resulted on the publication of a white book [1] by the project leader, Professor Alain Vaucelle. The "Project convergMPEG-SCORM" was the departing point for this Thesis.

Concerning this, a primary objective of this Doctorate research is studying the increasing convergence between the audiovisual industry and multimedia ICT, comprising also the technologies for education. So regarding the switch off of the analog television broadcast, that allows the integration between both domains in the context of the digital Era.

1.2 RESEARCH PROBLEM

The Engineering problem of this research, carried out in the framework of the Program of PhD on Electrical Engineering at the Department of Telecommunications and Telematics of FEEC UNICAMP, followed under direction of the Professor Doctor Yuzo Iano, is situated in the field of digital Information and Communication Technologies applied to Education (ICTE), proposing a project of technological innovation and knowledge for understanding the research on the standardization of metadata in both applications for e-Learning, how much of the universe of multimedia (MPEG) and the development of applications and learning objects interoperable digital video, particularly for Digital TV. Considering the reality of digital convergence multimedia in which humanity lives nowadays, it is extensible to any video support in a digital format.

In this way, it aims to achieve the State of the Art in academic research about interoperability and reuse of applications and learning objects, proposing to search for a possible pattern appointing towards the concept of “SCORM MPEG Video”.

Regarding the presented issue, the academic community faces this research problem of developing an interoperable matching for normative bases, achieving an innovative proposal in the convergence between digital telecommunications and applications for e-Learning, also essentially multimedia.

Therefore, departing from a compared study, and applying a methodology, proposing a project of technological and knowledge innovation due to this contribution to the development of metadata standards to interactive Digital TV on MPEG video format, exploring the different MPEG family of formats in question: MPEG-4, MPEG-7 and MPEG-21, as well as the most recent and less studied too, these formats in standard-setting process at ISO / IEC JTC1 SC29 subcommittee.

So to achieve this purpose the cited methodology adopted consists on building an Ontology which could make possible the interoperability between the multimedia and e-learning metadata formats and its digital media objects created.

1.3 THE SCORM MPEG-21 INTEROPERABILITY

Regarding the challenges for the standardization of the ICT applied to Education (the ICTE), it comprises a telecommunications engineering problem still in developing the issue concerning how the MPEG Video family, especially the MPEG-21 standard, could offer a normative basis for the implementation of multimedia metadata related to e-Learning, as Vaucelle [2] stated.

ADL strategy lies on capitalize the other subcommittees norms, and encourage the adoption of the Part 5 of the norm MPEG-21 (2002) – REL, or Rights Expression Language, to solve copyright issues, besides it delegates to the LOM standard its metadata description (or parts to other standards like IMS or DCMI – Dublin Core).

This reveals a very converging approach and acceptation concerning the metadata and MPEG-21 issue on the industry and market.

Since then, research the standardization of specifications and operation of learning objects in digital video in accordance with the standards surveyed by SC36 subcommittee.

In France [2] there was concluded an innovative research project, which serves as a reference and doctoral training, researching an MPEG video standard (based on MPEG-21) related to the metadata standard for SCORM learning objects.

Thus, proposing interoperable, reusable, referenceable, indexable learning objects metadata in video format, through technology employment, the basis for the development process of this new candidate standard – MPEG-21 SCORM.

Considering also that there are other consolidated metadata standards beyond the modes of SCORM (LOM, IMS, AICC, METS, Tin Can

API) and also that there are researchers and scientific literature that we list the MPEG-21 DIDL standard as the more generic approach for this purpose use structural description metadata.

2. OBJECTIVES

As a general objective, from the Engineering research problem approached here, we intend to investigate the interface between the scientific and technological production areas of Multimedia and Education mediated by digital Information and Communication Technologies.

The mean to achieve this general purpose was building an Ontology which could make possible the interoperability between educational applications in Digital TV environments and to facilitate the transposition of audiovisual digital media produced on TV or on the Web platform, for its use for educational purposes. This ontology can perform the role of a translator between the metadata standards between both domains.

The practical purpose is the creation and storage of video in the form and concept of “video objects”, or “digital items”, for their use and reuse in digital telecommunications as Digital Television and video channels on the internet; as well as for its use as learning objects in an interoperable system for the e-Learning industry.

Given that the ontology proposed behaves as description metadata for all sorts of media and hypermedia, and aims to create and manage learning objects for the educational and software fields.

In order to develop this ontology it was mandatory to study the norm ISO MPEG-21 as well as the SCORM norm.

This ontology is also applicable to audiovisual digital libraries providing educational services to their users.

3. METHODOLOGY, HIPOTHESIS AND EXPECTED RESULTS

To reach the purpose and challenge within the research problem presented, it is proposed to create a standard ontology of interoperable metadata applied to the web, the Digital TV and extensions for mobile devices, a match of metadata schemas based on the integration between MPEG-21 and SCORM metadata standards.

The methodology used consists on building an ontology between MPEG-21 SCORM which can be achieved on making a correspondence through the XPath language, managed by the W3C.

The employ of the XPath language is desirable for matching and mapping both metadata schema patterns – integrating MPEG-21 (mostly Digital Item Declaration Language) and SCORM metadata schema. The practical purpose is the creation and storage of objects for use in digital telecommunications as Digital Television, in an interoperable way with the e-Learning industry, here as description metadata for all sorts of media and hypermedia to create learning objects.

The implementation allows the transformation of MPEG-21 metadata to SCORM metadata for the creation of SCORM compatible courses that utilize educational material from TV programs.

This hybrid ontology, possibly claimed as a new hybrid metadata standard, would allow the creation and storage of objects for use in digital telecommunications, operating on media like Digital Television, in an interoperable way with the e-Learning industry, which in its turn employs all sorts of media and hypermedia technologies to create learning objects.

The employ of the XPath language is desirable for matching and mapping both metadata schema patterns – integrating MPEG-21 (mostly referring to the Digital Item Declaration Language part of this normalized format) and also the SCORM metadata schema.

Thus, the application of this Ontology consists on mapping both standards, allowing the interoperability between the two metadata standards, which is traduced in their parallel transformation or conversion, from MPEG-21 metadata to SCORM metadata and vice-versa, thus creating compatible courses that utilize video material from TV programs for educational purposes or, in the other hand, audiovisual digital libraries providing educational services to the Digital TV users.

PART 2 – METADATA FOR THE MULTIMEDIA AND THE ICTE

4. METADATA FUNDAMENTALS: MULTIMEDIA VIDEO AND ICTE LEARNING TECHNOLOGIES

4.1 METADATA: CONVERGENCE AND STANDARDIZATION

When we talk about convergence, we talk about the convergence of platforms, networks, formats, technical standards, software, but also in an essential way, the convergence of content, languages, media and uses of technologies. This is the Convergence context that is glimpsed and proposed to integrate Video Multimedia and ICTE, through the recent researches that express the State of the Art nowadays.

This convergence has as effect that the media tools (platforms, networks), as well as the information content and its flows and are more and more versatile, more multimodal (image, text, sound, robotics, automation, three-dimensional environments, virtual reality, augmented reality), and more parameterized standards.

Convergence features as other use effect the fact that these media tools fall increasingly in the context of integration services, so they are related to e-procurement processes involving therefore market factors. As a result, there is also a relative homogeneity and consistency an insertion in the ICT environment.

This convergence would enable a dynamic approach between experts of ICTE, or e-learning (which make up the SC36), and the broadcast world experts, such as digital TV (comprising the SC29[3] and standardize multimedia standard MPEG video).

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[3] SC29 Group website, based in Japan, can be accessed on: <http://www.itscj.ipsj.or.jp/sc29>.

These two traditions of practice have a common heritage of educational resources that still maintain the mark of the two recording logical, data descriptions and use: on one hand logic of SCORM and LOM from the SC36, and in the other hand the MPEG logic of structure. Both based on XML markup language.

Nowadays, there is a need to produce a set of coherent metadata which can imply these two universes of use and, over all, to take into account the two cultures of standards and normalizing, in a single “meta-package”.

The progress of the convergence and interoperability has become completely congruent with the ICT development.

First, this progress is highly dependent on changes from more consistent standards and coordinated within the various families of standards developed in JTC1 standards.

Secondly, progress depends on the establishment of a technological normative commitment of vital importance (in both industrial and social levels, so the economy) and established as a government priority in Brazil and in the world: the programmed switch off of all radio and TV analog broadcasting, in favor of the only and mandatory digital transmission.

Different researchers implied in studies in the field of knowledge and who are internationally experts in the standardization of ICTE (SC36, SCORM) and / or multimedia (MPEG) find that for both, speaking in terms of standardization of ICTE as to MPEG, the synergy is still too weak and redundancies (specially form the SC36 field of domain) are highly present and must be carefully analyzed.

The study on the development of a standard SCORM metadata in MPEG video, creating learning objects in standard video format, has the possibility, therefore, that the systematic exploration of fields and features normalized by these two large groups of experts could expand technical and scientific knowledge, and thus allow each of these instances of normative influence evolve in its development strategy of your respective standards families (MPEG and ICTE) and even integrate them for mutual growth.

The proposed synergy between the ICTE and MPEG could be expanded in order to eliminate redundancy between the two standardization bodies (SC36 and MPEG).

It is a fact that in many countries were developed before or after the 2nd World War the use of the radio and later the television to formal school learning, initiatives that persist today in many of them. This phenomenon is not restricted to northern countries, said developed, but is much explored in countries under development, such as Brazil itself.

The normalization of ICTE few decades ago constituted a pioneering activity that has been further became more and more complex by the global convergence of networks, multimodal language and multimedia – here the digital video.

4.2 DIGITAL TELEVISION AND ICTE: TOWARDS A STATE OF THE ART CONVERGENCE

The technological innovation issue comprehends a research in a hybrid field that comprises a breakthrough on the media convergence process, on purposing an interface between the norms and standard implemented in the field of interactive multimedia, highlighting the Digital Television (normalized by the ISO SC29 subcommittee), and the field of the technologies for e-Learning (normalized by the ISO SC36 subcommittee).

The whole bunch of ICT is subject to convergence and interdependence of media. These techniques rely heavily on standards that are negotiated and designed in standard-setting bodies.

An important role of ISO / IEC JCT1 is working on the convergence of instances that define both components and services attached to these topics.

It is proposed to analyze the constraints of possible convergences between the MPEG family norms (conceived by the JCT1 SC29, the standards body that carries MPEG) and those of the ICTE (the ICT for Education, work under responsibility of the JCT1 SC36), in particular the SCORM metadata standard, as well the future "SCORM 2.0" standard.

As a second decisive state, it is therefore mapped the prospective normative framework matched between MPEG-21 multimedia document and the normative world of ICTE, focusing on SCORM normalization.

The final purpose of the project, so to speak, is to provide the specification of a hybrid Ontology mapping the MPEG-21 and SCORM metadata standards.

From this context, the research in conclusion propose the study based on the convergence of digital media working on the hypothesis of the integration of both ICT and ICTE focused on the telecommunications and the multimedia domain.

This convergence covers two breaking questions up to be solved in our digital era: the interoperability of data and formats; and the integration of the cited ISO working groups subcommittees.

Considering the challenges of standardization of Information and Communication Technologies applied to Education, constitutes a digital TV engineering problem still developing the question of how the MPEG Video family, through the MPEG-4 7 and 21 standards, could provide a normative basis for the implementation of metadata associated to ICTE.

Counting on the support of new digital technologies, the way educational content has been developed according to a technological paradigm in the form of Learning Objects is an interesting object for researching.

Including on this issue the e-learning video platforms called MOOC (stands for Massive Open Online Course) and Post-MOOC formats (“SPOC” – Small Private Online Course), whose educational content is provided as online video format. Those are formats which can be explored by the broadcasters as an innovative market as well.

This development requires an orchestration of all educational components (in addition to the actual video, still image, sound, text, hyperlink etc.) and should be within a legal framework in order to ensure interoperability, reuse and referencing by most platforms or virtual learning systems or even by digital television or other media which can be located beyond these classic educational environments.

Citing a number of commonalities already taken in progress in the area: Information and documentation (TC46); terminology and other language resources and content resources (TC37); terminographical and lexicographical working methods (TC37 / SC2). In fact, this leads to understand the scale of all works and activities that make up the JTC1, which will need to add expertise of multiple instances of the ITU (International Telecommunication Union) and W3C[4].

All regulatory bodies know a period of governance difficulties, since the exponential increase in the overall volume of production rules, knowing a multidisciplinary expertise deficit. After the optimism that accompanied the first implementation of provisions of the MPEG-1 and 2 families, the regulatory authorities should confront the development of new projects within the MPEG family.

This logic of reference for the digital document *corpus* is one of the baseline assumptions for information systems developers, so that you can create normalization with regard to software engineering (XML, MPEG-7, and MPEG-21). These principles are developed in all their dimensions by the subcommittee which deals with standardization for ICTE, the ISO/IEC JTC1 SC36 subcommittee.

[4] World Wide Web Consortium, entity that normalizes the web.

4.3 METADATA NORMALIZING SCENARIO FOR MULTIMEDIA AND ICTE

It is well-known that the normalization or standardization, on an international level of the media regulatory committee is accomplished by the ISO / IEC JTC1 SC29 and in turn, the normalization of ICTE is effected by ISO / IEC JTC1 SC36[5].

The ISO/IEC JTC1 SC36 is an instance of normalization that develops a family of standards for ICTE. The SC36 ("SubCommittee" 36) has defined sets of metadata for management and quality control of actors, educational resources, computing environments and networks.

Otherwise, the *e-procurement*[6] of teaching resources leads us to questions of law, routing resources, invoice or resource exchange and clearing services, management of legal, institutional, registration, evaluation and certification. All these issues are currently analyzed on an individual basis as well as its proposals, even if they arise from the same overall logic integration services.

Regarding the two normalizations at issue, a convergent point of view, it can be seen that the MPEG-21 will become the inevitable format for the universal standard integration into global digital multimedia, conceived and organized by the multimedia area.

However, MPEG-21 will not be able to consolidate itself as the integrator of multimedia fields of study beyond the ones it comes from originally (the audio-visual entertainment and information) without relying on significant efforts of ownership and regulatory development. These efforts,

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[5] We will adopt the acronyms SC36 and SC29 for the corresponding Subcommittees.
[6] Purchase and sale of supplies, work and services over the Internet (either B2B, B2C and B2G e-commerce models) as well as other information systems and networks, such as electronic data interchange and enterprise resource planning.

which should be coordinated by competent and responsible government agencies, are contributory responsibility of standardization bodies that correspond to other scientific fields of study involved.

Even if the multimedia normalization could be highly related to the ICTE (SC36), it was found that most of the experts in this instance are no more than vaguely aware of the MPEG-21 appropriation and adaptation efforts (the same about MPEG-7 e 4) that should be done. Copyright, as well as the management of e-legal, appear outside the cultural field of the majority of the SC36 experts.

It is much less the case, on the other hand, the delegates or experts from ADL[7], that developed the SCORM[8] [10], standard, participate on the SC36 meetings and propose to explore MPEG-21 to solve a family of regulatory features that should be developed to make the norms of ICTE feasible technically and economically.

[7] Advanced Distributed Learning, USA Department of Defense sector that developed the SCORM metadata standard.
[8] Sharable Content Object Reference Model.

4.4 NORMATIVE BASIS: THE INTERRELATION BETWEEN MPEG GROUP AND SC36 RESEARCHES

In a context of global understanding and extension of e-procurement for education, we intend to analyze in this thesis as the MPEG-21 could provide a normative basis for the metadata of the universe of ICTE.

SC36 features a multidisciplinary work orientation; since the MPEG-21 takes place in a modular development framework. SC29 normalization work otherwise was concentrated on the MPEG Group.

Nevertheless, it appears still endure one interdisciplinary deficit within the standardization world, although the recommendations to explore the MPEG-21 at the level of e-procurement of ICTE have been discussed for years as an engineering problem and their productive implications.

The orientation of all work of JTC1 SC36, as can be followed by the IEEE [11] is essentially based over the portability, interoperability and cultural adaptability of the information technologies for education. SC36 is not able, therefore, to double or even extend the work previously carried out by other technical committees, such as the SC29 itself, the media committee, which was all about the sound encoding, image, multimedia and hypermedia information.

ADL, creator of SCORM standard, has a role as partner level A to SC36 – acting on the subcommittee in question, its strategy is to capitalize on the standards of other SC.

Mostly they currently demand fostering the adoption of Part 5 of MPEG-21 (Rights Expression Language), to resolve copyright issues, and delegate to the LOM[9] standards (or other learning metadata formats such as

[9] Learning Object Model, metadata standard previous to SCORM that remains in use.

Dublin Core or the future MLR) to take care of describing learning resources in its different views. Clearly, this description would become competitor of the issues of MPEG family multimedia standards.

At first, the work will undergo a specification (technical requirements) for – learning objects, associating experts of both worlds – Education and MPEG Video. The idea of the ADL is to, in a second stage of integration, proposing that the SC36 experts rethink the possibility of unifying the normative description of the multimedia document as a learning resource.

In the MPEG environment, two contrasting scenarios are envisioned. The first highlights the MPEG Group interest in becoming proactive not only in the field of broadcast uses, such as Digital TV, but also within the converging world of uses of ICTE.

In the second scenario, the MPEG community expects to have repaid their broadcast investments on aiming a second market toward convergent uses. A hybrid reality or the predominance of nuances can be set in a future vision.

Regarding a scenario under this second configuration, the management will be held from the MPEG components or from the learning objects components from the traditional standards associated with the SC36, considering the ongoing development and standards that will take into account new features which relate to the MPEG-21, 7 or 4 standards, adapted to the new needs of transmission.

However, it would be fundamental and logical that we should build a bond or partnership between SC36 and SC29 reflected in a joint working group – initiative yet inexistent and not very likely to happen.

In the SC29/WG11 side, the interest is the broadest possible development of general normative technologies. It would be necessary, therefore, that the experts were aware of the challenges at stake on the market of the ICTE and, in particular, of the ones presenting some added value.

MPEG-21 became a modular development platform (a framework) and standardization towards global integration for all multimedia documents. The multimedia is not the product of a particular knowledge area, but it is a direct consequence of the normalization of digital practices, as for the developers on telephony, audiovisual and computer technology.

It is a digital practice put in accordance within the instances of standardization to be advantageous to interoperability and compatibility. This procedure led to the global digital multimedia standard we know today, under the auspices of the e-procurement.

The standardization of ICT is more and more like a practice consisting in offering production platforms or frameworks to the industry.

Despite the MPEG-21 have arisen from a community that focuses on audio and video, the so called MPEG-21 framework can accommodate all kinds of complex digital objects, such as the electronic text, digital magazines, scientific data and so on, composing a broad digital library.

The strength of the MPEG-21 format resides on its ability to offer a general platform for the system of standardized production and distribution of all digital content.

This way, it is desirable that the experts of the Committee dealing with the standardization of ICTE, *e.g.* SC36, can take ownership of MPEG-21 and add to its structure the specificities of the world of ICTE, always within the general framework of the standardized system of production and distribution of digital content offered by this specific format.

The channel for this evolutionary step would be the collaboration between SC26 subcommittee and the SC29 MPEG Group, so to promote the definitive regulatory solutions that the industry and the users need, in the medium and long term.

In this context, for all multimedia application the MPEG-21 specification constitutes a privileged framework, easily accepted by the end user, and extensively developed by the industry and the academic community, which feed the research.

4.5 THE NORMS COMPOSING THE MPEG VIDEO FAMILY: MPEG-1, 2, 4, 7, 21 AND OTHERS

Following the optimism that accompanied the first MPEG family implementation provisions (MPEG-1 and MPEG-2), the regulatory authorities must confront with the development of new projects, within the own family MPEG video.

According the *Moving Picture Experts Group* (MPEG), MPEG-1 is a "suite of standards for audio-video and systems particularly designed for digital storage media". MPEG-2 is a "suite for standards for digital television" [4]. On the other hand, MPEG-4 is a "suite of standards for multimedia for the fixed and mobile web"; and MPEG-7 is a "suite of standards for description and search of audio, visual and multimedia content" [4].

MPEG-21, however, is a "suite of standards that defines a normative open framework for end-to-end multimedia creation, delivery and consumption that provides content creators, producers, distributors and service providers with equal opportunities in the MPEG-21 enabled open market, and also be to the benefit of the content consumers providing them access to a large variety of content in an interoperable manner" [4].

It can be noticed from these definitions that the main characteristic for MPEG-4 is the possibility of object creation and manipulation.

For MPEG-7, the main gain achieved by its adoption would be the metadata description of all media content only.

MPEG-21, as its major characteristic, allows the modelling of entities, entities which could comprehend content and an object oriented domain of descriptors as well.

Still from the perspective of this analysis, in this research we could conclude that MPEG-21 become the most suitable option for metadata description as a breakthrough in this field since its framework allows not only content description, but all kinds of elements presented within the consumption channel, from the content and object creation, through broadcasting and reaching the end user (who otherwise can perform the role of a producer as well).

After treating the issues concerning the optimized compression of information (formats MPEG-1 and 2), the experts group MPEG started operating on much more ambitious regulatory scenarios:

- MPEG-4: organization of audiovisual and multimedia standards deeply and fully interactive structured in accordance with the principles of markup languages.
- MPEG-7: organization of documentary standards for the domain.
- MPEG-21: organization of the services integration along the entire multimedia domain (which implies the creation of a layer of e-procurement, mainly from when the multimedia becomes interactive.

Actually it is very complex to predict the type of ownership, or even misrepresentation of uses that will result in new features offered due to the family of MPEG standards. How can they evolve and get a grip on the current activities of the audiovisual television business? Which tasks will appear or disappear in the productive process of Interactive Digital TV (from production to post-production, to storage and distribution of digital content through media channels)?

This dynamic will go on and be amplified: the choices of data integration and components proposed by MPEG-21 will have got the regulating effect which we underline. This is a fact admitted by many analysts of technological developments and normalizing.

It can then be imagined a very simple scenario: an interactive educational content, accessible on any digital screen (TV, computer, smartphone, tablet, videogame console etc.) from any digital data network via IP protocol.

In fact, over the years the MPEG family has expanded to a much larger diversity than just these five already mentioned.

By the year 2016, JC29 Subcommittee (based in Japan) has published studies on the following types of MPEG format, which constitute the MPEG family [4]:

- **MPEG-1**
- **MPEG-2**
- **MPEG-4**
- **MPEG-7**
- **MPEG-21**
- **MPEG-A**
- **MPEG-B**
- **MPEG-C**
- **MPEG-D**
- **MPEG-E**
- **MPEG-V**
- **MPEG-M**
- **MPEG-U**
- **MPEG-H**
- **MPEG-DASH**

MPEG-1

A suite of standards for audio-video and systems particularly designed for digital storage media. Coding of moving pictures and associated audio at up to about 1.5 Mbit/s

MPEG-2

A suite for standards for mainly developed for digital television. Generic coding of moving pictures and associated audio.

MPEG-4

A suite of standards for multimedia for the fixed and mobile web. Coding of audio-visual objects

MPEG-7

A suite of standards for description and search of audio, visual and multimedia content. Multimedia content description interface.

MPEG-21

Constitutes a *multimedia framework*.

A suite of standards that defines a normative open framework for end-to-end multimedia creation, delivery and consumption that provides content creators, producers, distributors and service providers with equal opportunities in the MPEG-21 enabled open market, and also be to the benefit of the content consumers providing them access to a large variety of content in an interoperable manner.

MPEG-A

A suite of standards specifying application formats that involve multiple MPEG and, where required, non MPEG standards. Treats about application formats.

MPEG-B

MPEG systems technologies. A suite of standards for systems technologies that do not fall in other well-established MPEG standards.

MPEG-C

MPEG systems technologies. A suite of video standards that do not fall in other well-established MPEG Video standards.

MPEG-D

MPEG audio technologies. A suite of standards for Audio technologies that do not fall in other MPEG standards.

MPEG-E

MPEG multimedia middleware. A standard for an Application Programming Interface (API) of Multimedia Middleware (M3W) that can be used to provide a uniform view to an interoperable multimedia middleware platform.

MPEG-V

Media context and control. MPEG-V outlines an architecture and specifies associated information representations to enable interoperability between virtual worlds (e.g. digital content provider of a virtual world, gaming, simulation), and between real and virtual worlds (e.g. sensors, actuators, vision and rendering, robotics).

MPEG-M

Multimedia Service Platform Technologies. MPEG-M is a suite of standards to enable the easy design and implementation of media-handling value chains whose devices interoperate because they are all based on the same set of technologies, especially MPEG technologies accessible from the middleware and multimedia services.

MPEG-U

MPEG Rich Media User Interface. MPEG-U provides a general purpose technology with innovative functionality that enables its use in heterogeneous scenarios, such as broadcast, mobile, home network and web domains.

MPEG-H

Suite of standards for heterogeneous environment delivery of audio-visual information compressed with high efficiency. High Efficiency Coding and Media Delivery in Heterogeneous Environments.

MPEG-DASH

DASH (stands for *Dynamic Adaptive Streaming over HTTP*) is a suite of standards providing a solution for the efficient and easy streaming of multimedia using existing available HTTP infrastructure (particularly servers and CDNs, but also proxies, caches etc.).

5. METADATA FOR DIGITAL TV AND THE ICTE

5.1 THE MPEG METADATA FOR THE MULTIMEDIA AND DTV

MPEG is intimately connected to digital audio and video. Established in 1988, the Moving Picture Experts Group (MPEG) has developed digital audiovisual compression standards which have changed the way audiovisual content is produced by the industry, delivered through a wide range of distribution channels and consumed by a variety of devices and publics.

Some years ago the SC36 experts came to consider that several segments of this Subcommittee could get started in a process of reformatting, since the MPEG normative development is already solved or ongoing [13].

In a general way, the objectives of MPEG metadata standards are normalizing content-based description for various types of audiovisual resources; allow quick and efficient content localization; address a wide range of applications, going beyond the pure content description, providing user preferences etc.

The types of resources of audiovisual information composing the documents structure could be: audio, speech; moving video, still pictures, graphics, 3D models; information on how objects are combined in scenes; descriptions independent of the media support; existing solutions for textual content or description.

After the MPEG-1 and 2, both standards which have made possible the video DVD and, more recently, Digital TV, the MPEG-4, MPEG-7 and MPEG-21 are the latest standards in the agenda of the SC29. These three fit together on an interdependent way one another, or so can extend or complement each other in a coherent way.

Having completed MPEG-2, MPEG could mobilize its energies to plan its work beyond MPEG-4. That work turned out to be the ideal continuation of the work proposed within the MPEG-2 Era, *e.g.*, to define a standard for audiovisual information representation that could describe or express the semantic meaning of the information and therefore enable people to discover what is in a set of audiovisual objects without having to actually access the information itself.

New MPEG standards have always presented cultural challenges. The development of MPEG-1 provided the first opportunity from different industry segments, mostly consumer electronics and telecommunications.

MPEG-7 is, conceptually, an audiovisual information representation standard, but the representation satisfies very specific requirements. MPEG-7, and later MPEG-21, fulfilled a key function in the forthcoming evolutionary steps of multimedia.

As much as MPEG-1, MPEG-2 and MPEG-4 provided the tools through the current abundance of audiovisual content could happen, MPEG-7 and MPEG-21 provided the means to navigate among content, even if yet unexplored.

In appropriating and adapting the MPEG standards (through the MPEG-4 and MPEG-7, in the first moment), it becomes possible to develop much more focused issue of interactive video teaching itself. It is counterproductive to solving the problems of management and multimedia integration within the scope of SC36 since these problems are handled by MPEG Group experts.

If the MPEG has great chance to be successful from this regulatory framework of multimedia to a large extent this is due to the fact that it is empowered by economic factors that cannot be compared to the other key standards such as ASCII[10], TCP IP[11], or the HTML[12] and the XML[13].

Technically, Digital Television lies within the field of MPEG multimedia, since it employs as its exhibition format the digital video standard MPEG-4 AVC H264, the worldwide industry standard today. Here, still not yet considering the new H265 (also called HEVC – High Efficiency Video Coding) standard codec, already normalized by the ISO under concern of the MPEG – Moving Pictures Experts Group.

However, the standardization of the multimedia MPEG is not restricted to MPEG-4, since other MPEG technologies are in process of specification by the SC29 subcommittee and actually are more powerful in terms of metadata description and so on, as MPEG-7 and MPEG-21.

These different MPEG standards and its characteristics, in terms of quality of encoding, compression efficiency and interactivity are summarized in Figure 1, translated from the source reference in French:

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[10] American Standard Code for Information Interchange.
[11] Transmission Control Protocol Internet Protocol.
[12] HyperText Markup Language.
[13] Extensible Markup Language.

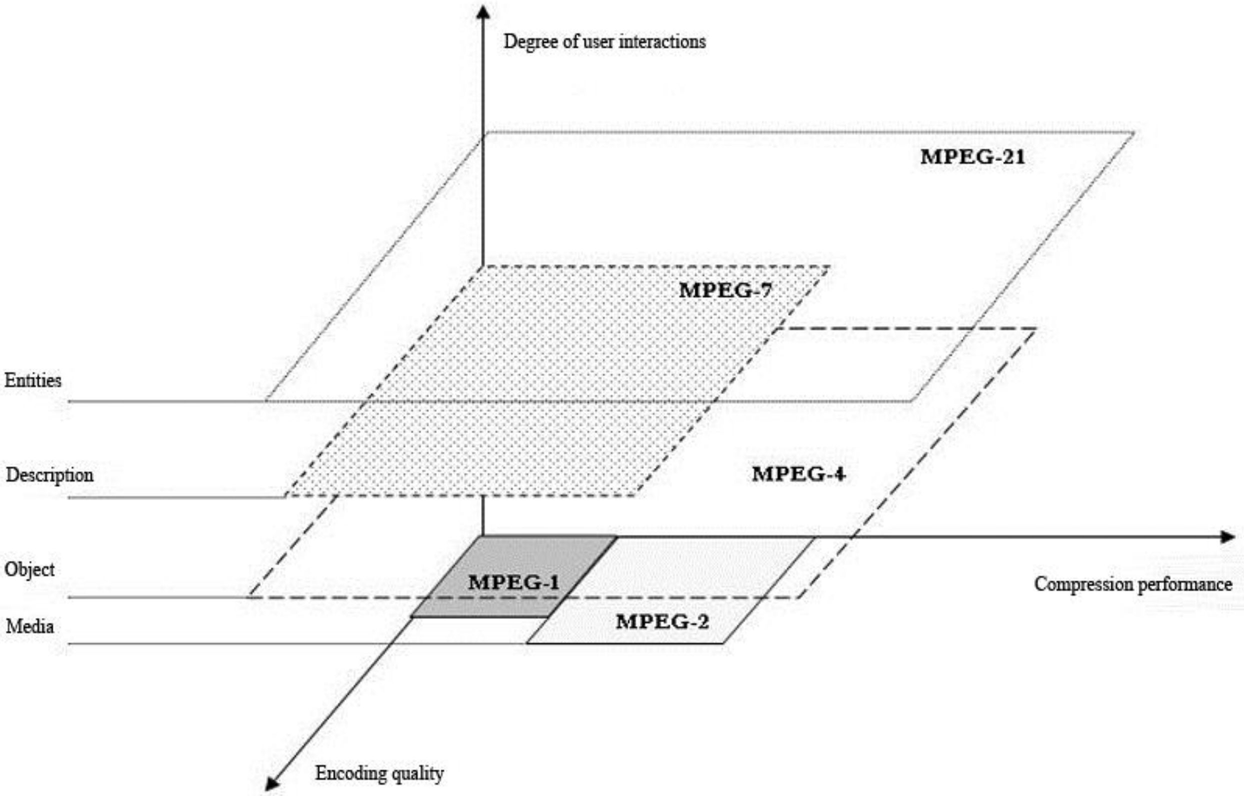


Figure 1–MPEG standards and its characteristics, in terms of quality of encoding, compression efficiency and interactivity [6].

As it can be inferred from the figure, it is demonstrated a three dimensional axis representation for the more important MPEG video formats in this times, according to three essential quality variables: Compression performance, Degree of user interactions and Encoding quality.

Firstly, concerning MPEG-1 and MPEG-2, it is evident the two dimensionality to that only these two formats are limited to achieve. Their degree of user interaction is fundamentally zero. Video files encoded in MPEG-1 or MPEG-1, as shown in the graphic, are simple media files. The evolution registered from MPEG-1 through MPEG-2 was centered only on the Compression performance and Encoding quality of the motion frames.

MPEG-4, in its turn, offers an evolution funded on improvements of Compression performance and Encoding quality, but most notoriously on the raising of a certain Degree of user interactions allowed by this video format.

They can be considered objects, not simple media assets, making possible to manipulate them as digital items through object-oriented coding and a certain metadata level of details.

The evolution observed concerning MPEG-7 is very impressive in relation to metadata description. MPEG-7 made possible to achieve a high level of details on coding description, providing a range of data of great importance for the industry interactivity demands, as well as user demands. But its compression performance is not quite the same as MPEG-4.

MPEG-21, in its turn, presents a remarkable advance concerning all the criteria, especially about the high degree of user interactions achieved. It makes use of the MPEG-7 description metadata, it has its own specific metadata, and the video quality is the same as MPEG-4 or any other, since it employs virtually any video format file in its digital items. It is the cutting edge format of its times, offering a state of the art experience in all senses for the user and the producer of content.

That demonstrates why the MPEG-21 metadata standard file format was the chosen one for creating an interoperable ontology to integrate the multimedia to the e-learning data production and consumption.

5.1.1 MPEG-2 and Digital Television

MPEG-2 changed the industry environment radically.

The number of television programs started multiplying by orders of magnitude. First, because more television programs in digital form could be packed in the bandwidth that used to carry one television program and second, because of the ability to make new offerings, making scalability possible for audio and video in digital format.

DVD compact discs could be used to store TV series, soap operas and movies (from TV broadcasters or even the movie industry), and also more advanced formats like Blu-ray discs.

MPEG-2 is the basis for the universal reference systems architecture for Digital Television. It is naturally a layer-based architecture, as follows [7, pp.29-31]:

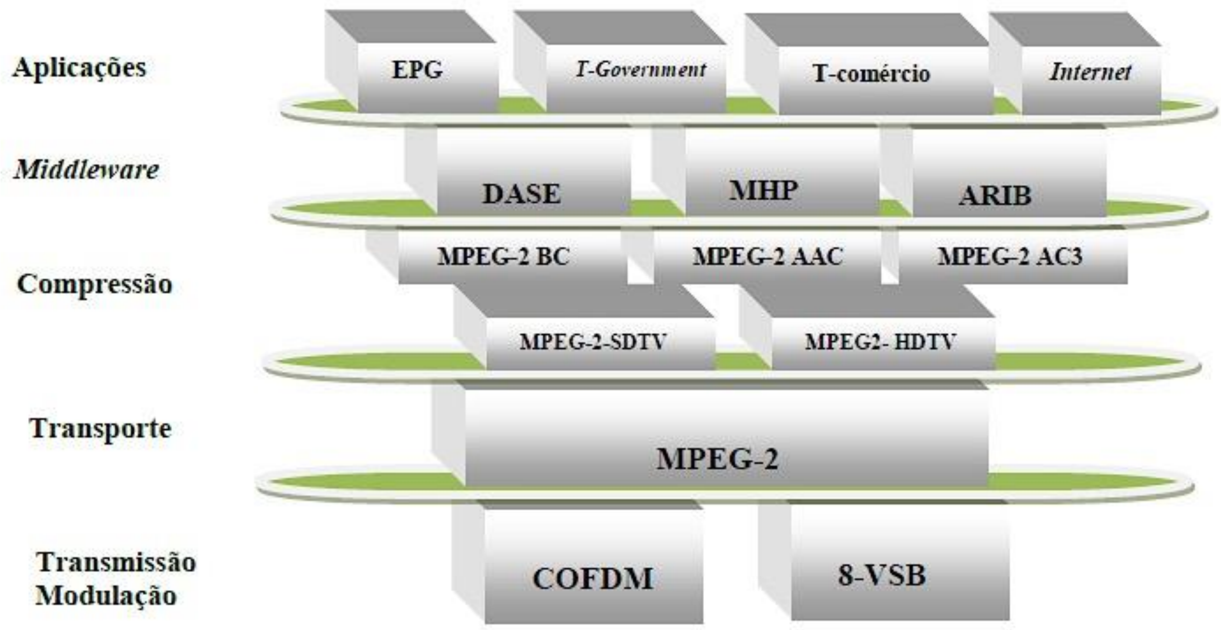


Figure 2–Reference architecture for Digital Television: layers and technologies [7, pp.29].

In this Figure we can highlight:

EPG: Electronic Program Guide;

“T”: Television;

DASE: Digital Television Application Software Environment (North-American standard);

MHP: Multimedia Home Platform (European standard);

ARIB: Association of Radio Industries and Business (Japanese standard);

MPEG: Moving Picture Experts Group;

BC: Backward Compatible (with MPEG-1 audio format);

AAC: Advanced Audio Coding;

AC: Audio Coding;

SDTV: Standard Definition Television;

HDTV: High Definition Television;

COFDM: Coded Orthogonal Frequency Division Multiplexing (European, Japanese and Brazilian standards);

8-VSB: Eight Level Vestigial Sideband (North-American standard).

The modulation layer (or transmission) is responsible for three services:

- Transmission and reception services that have the function of amplifying the signal at the transmitter and tune the signal at the receiver;
- Modulation and demodulation of services that are responsible for modulation and demodulation of the encoded transport stream;
- Encoding and decoding services that are responsible for coding and decoding transport stream.

The transport layer, within the service provider side (station), is in charge of performing the multiplexing of several programs into a single stream of transport. At the receiver side, it does demultiplexing the transport stream in accordance with the user-selected program.

The compression layer, on the other hand, is responsible for compression and decompression of audio and video signals on the side of the station and on the user side, respectively.

The application layer, in its turn, is responsible for the execution of applications. It corresponds to the visible layer to the user.

Finally, the middleware layer is a layer of software responsible for standardizing the service offered to the application layer, hiding the peculiarities of layers with-pressure transmission and modulation.

Related to the transmission within MPEG-2 sections, to transmit AC3 audio data through specific MPEG-2 sections, one of the following transmission methods shall be used:

- As an elementary stream AC3 audio file;
- As a file of multiplexed stream into the TS format.

It is important to notice that while receiving a broadcasting service and play a TS file received through specific MPEG-2 sections, two separate transport stream processing systems are required.

5.1.2 MPEG-4

MPEG-4 (ISO/IEC 14496, 2000), video format norm started in December 1999 in its first version, comes to audiovisual 2D/3D objects and natural or synthetic and does not cover encoding selective objectives and composition of scenes. The norm offers, therefore, an environment of generic tools as well as new features of universal access and interactivity.

For the large inventory of features supported, the ISO/IEC MPEG-4 revolutionizes completely the world of digital multimedia [9].

In effect, a stream MPEG-4 is a rich media video content, which covers various details of the different individual objects considered as length of lifecycle, support regions, positioning within a scene and so on. It's a natural tendency the possibility to further enrich this representation, through associating different objects of specific descriptors that unfold on the new features, such as automatic access and content requests.

This will be the subject for the MPEG-7 (Multimedia Content Description Interface: MCDI) norm.

As well as the example about the MPEG-2 standard, the MPEG-4 is also a layer-based architecture, structured as follows in Figure 3 [7, p.37]:

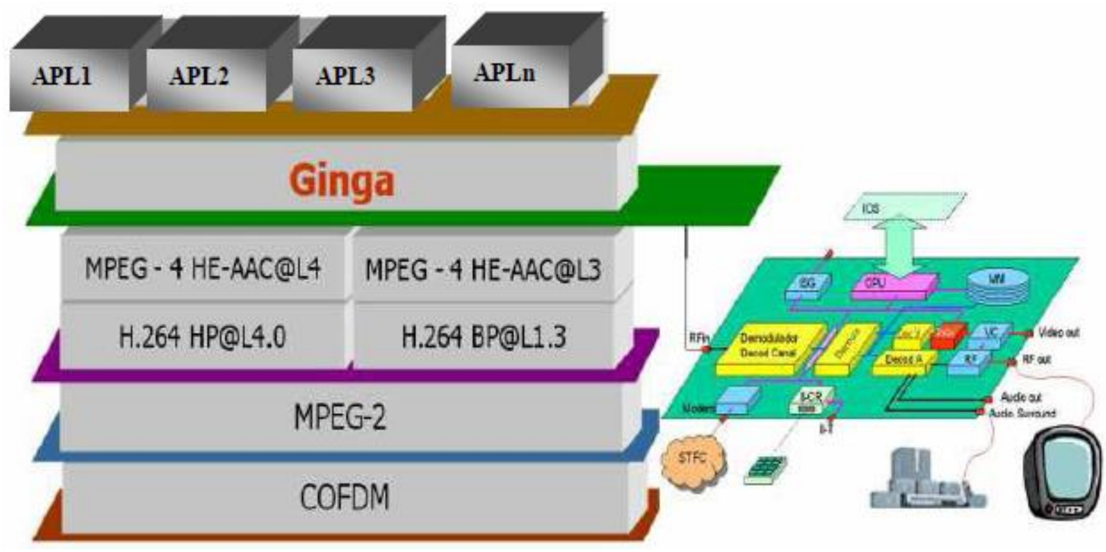


Figure 3–Reference architecture for the Brazilian System of Digital Television (Ginga): layers and technologies [7, p.37].

The main differences between the Brazilian and the Japanese standards are the encoding (H.264 / MPEG 4) and the middleware. The stream of pulses remains throughout the MPEG-2 standard, but the compression standard is H.264 in the Brazilian system.

The MPEG-4 standard can represent media content in the form of objects. This characteristic is quite suitable in the use of Digital TV; it allows the dynamic manipulation of video, allowing, for example, the combination in the same video of images captured with synthesized objects.

Another important feature of MPEG-4 is the fine-grained scalability (FGS, or Fine Grain Scalability).

The FGS technique is very important in the dissemination of videos as to generate a single stream representing the highest level of video quality, but allows lower quality levels to be extracted from this when necessary (for example, when the CPU clients are not able of sufficient processing).

It is also visible the middleware layer, called Ginga for the Brazilian DTV system, not highlighted here because that is not actually the focus of this particular research, but which deserves the observation.

5.1.3 MPEG-7

MPEG-7 (ISO/IEC 15938, 2002) [32] specifies a palette of standard tools to index and describe syntactically, automatically or semi-automatically, all multimedia content.

The same information can therefore be treated according to the surveyed, ranging from spatial-temporal communication capabilities (audio and video handled separately) to a semantic description of the data flow.

The MPEG-7 norm can join the other descriptors, to specify the format, access conditions, their hierarchical structure, and its relevant links in relation to initial information, the context of recording or diffusion of the assets. It provides the ability to browse, query, filter and take ownership of the information within an open multimedia body [31].

This pattern of the MPEG family was developed to match the other standards used in the different fields of application recommended by the W3C.

For the knowledge, one can cite: XML; ETF (Internet Engineering Task Force, which offers Internet-related standards); the norm for Dublin Core metadata; norms which refers to the terminology and languages resources of ISO TC37; metadata that ensure the exchanges between operations (image, sound, alphanumeric data); the establishment of open systems for Interactive Digital television applications; the ISO/IEC 11179, 2003 on metadata registries.

However, MPEG-7 does not include any private information on the use of multimedia objects in the field of education. For the simple reason that if it is a non-specific standard application. By this fact, today the MPEG-7 is dedicated exclusively to descriptions of multimedia content and is completely independent of the transmission channels and terminals.

However, the world of multimedia applications and of ICTE in particular cannot ignore the diversity of communication networks, considering fixed or mobile terminals available today, and must propose services adapted to each one.

Scalability, adaptation and technological convergence become the keywords of the current multimedia. The challenge in this scenario is to ensure the dissemination of the contents and their descriptions, as well as of the services accessible everywhere, minimizing production costs and reusing the existing content.

5.1.4 MPEG-21

The MPEG-21 (ISO/IEC 21000, 2003) is one of the newest multimedia video formats developed by the MPEG group.

Called *Multimedia Framework*, it mainly proposes to solve this technological problem standardizing the descriptions of not only content, but also of all elements likely to intervene within a chain, from creation through distribution and even the end user.

The central concept within the MPEG-21 metadata standard can be understood as the DI - Digital Item, as defined in Part 2 of the standard [12].

The DID, or Digital Idem Declaration, relates a digital product, which can be simple or composite. A typical example is a webpage, containing different multimedia resources, such as text, image, video, formatting elements (*e.g.* CSS and XSL), hyperlinks, as well as dynamic coding scripts.

The MPEG-21 standard holds today 22 parts [13]. MPEG-21 is an XML-based metadata specification that brings two fundamental pillars:

- The definition of a unit or essential object of distribution and transaction, which is called *Digital Item*;
- And the notion of "reader" – the concept of users interacting with.

The MPEG-21 metadata standard partitioned in its 22 parts [13]:

1. Vision, Technologies and Strategy (Digital Item definition)
2. Digital Item Declaration
3. Digital Item Identification
4. IPMP (Intellectual Property Management and Protection)
5. Rights Expression Language
6. Rights Data Dictionary
7. Digital Item Adaptation
8. Reference software

9. MPEG-21 file format
10. Digital Item Processing
11. Evaluation methods for persistent association Technologies
12. Test bed for MPEG-21 resources delivery
13. *Scalable Video Encoding – Transferred to MPEG-4 AVC standard*
14. Conformance testing
15. Event reporting
16. Binary format
17. Fragment identification of MPEG-21 resources
18. Digital Item Streaming
19. Media Value Chain Ontology
20. Contract Expression Language
21. Media Contract Ontology
22. User Description

Each part will be considered, but the focus of this study lays mostly on the first three parts of the Norm ISO/IEC 21000, the MPEG-21 ISO Norm. Especially the ISO/IEC 21000-2, Digital Item Declaration, which is mandatory for the comprehension of the capabilities and option to the use of the MPEG-21 audio and video format over all others MPEG formats presented here, even over MPEG-7 file format.

Due to the importance of the norm to this research and to the fact It has not open access to the public, the ISO 21000 follows attached as an annexure to this Thesis (Annex A).

5.2 DIGITAL TELEVISION AND E-LEARNING METADATA

These days interactive television is gradually established whether on air broadcast, digital carrier packages, cable or on the internet. Regarding the radio broadcasters decision to adopt the MPEG-4 as the broadcasting standard for digital terrestrial television foreshadowed medium-term programs of various deals with certainly interactive features. And actually it can be kept this way if evolving the system, since the MPEG-21 Digital Item supports perfectly this format of resource, as Figure 4 demonstrates:

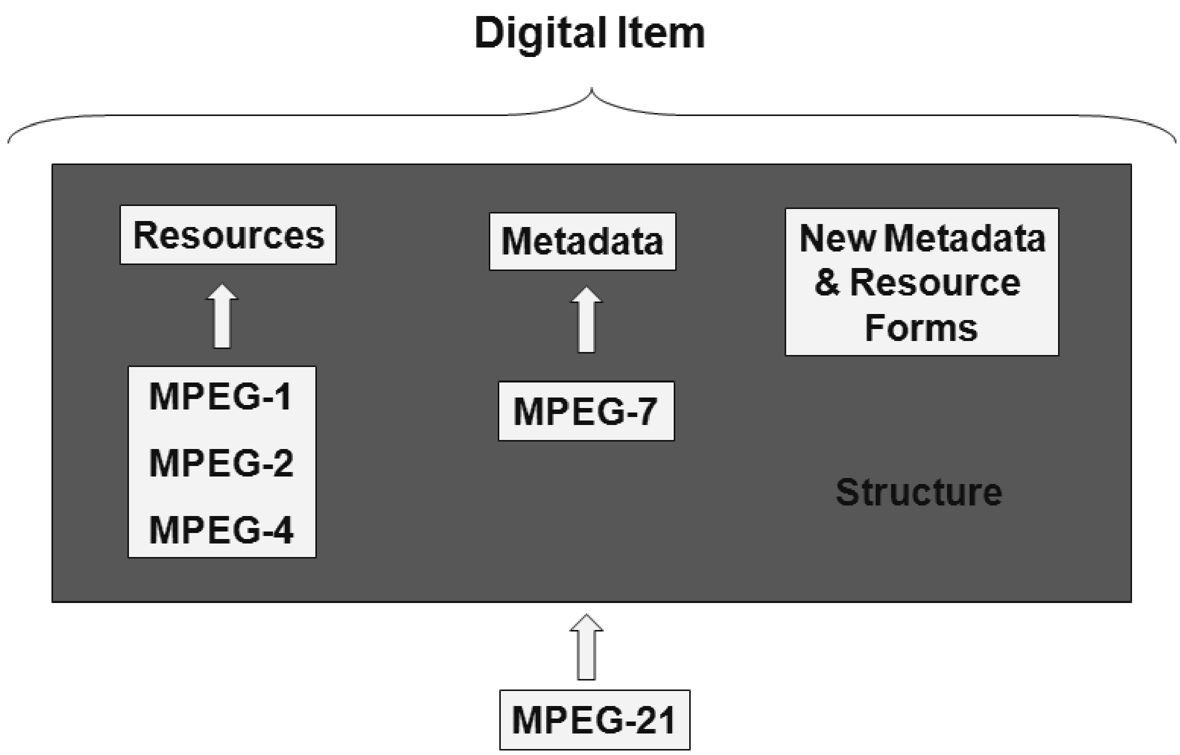


Figure 4–MPEG-21 Digital Item structure.

We can infer from the diagram that MPEG-21 digital item file structure makes use of the MPEG-7 description metadata, as well as offers its own specific metadata (new metadata), and the video quality is the same as MPEG-4 files or any other, since it employs virtually any video format resource in its digital items – including new ones (new resource forms).

The definition of a resource, as stated in the norm ISO/IEC 21000-2:2005(E) is:

> A *resource* is an individually identifiable Asset such as a video or audio clip, an image, or a textual Asset. A *resource* may also potentially be a physical object. All *resources* shall be locatable via an unambiguous address. [12, p.8].

A Digital Item (or DI), in its turn, is a structured digital object with a standard representation, identification and metadata. It constitutes the fundamental unit of distribution and transaction in the MPEG-21 framework:

Digital Item = Resources + Metadata + Structure.

This can be represented, as a title of example, by:

- Resource: individual asset, e.g., MPEG-2 or MPEG-4 video.
- Metadata: data about or pertaining to a resource or other part of an Item; descriptive information, e.g., MPEG-7.
- Structure: relationships about parts of the item.

In other words, the MPEG-21 Digital Item it is perfectly able to employ MPEG-4 audio-visual objects as well as MPEG-7 descriptors and description schemes.

MPEG-21, as already stated, provides the DIDL (*Digital Item Declaration Language*), but also other schemes and their languages, within other of the many parts of the standard, for the cataloging of objects and the flow of information, the case also DII (*Digital Item Identification*), and DIA (*Digital Item Adaptation*); but also for dealing with copyright data (MPEG-21 Part 5 REL - *Rights Expression Language*), CEL (*Contract Expression*

Language), IPMP (*Intellectual Property Management and Protection*); and even use cases (UD - *User Description*).

MPEG-21 provides the descriptive mechanisms of such digital specifications. In particular, the Parts 2 (Digital Item Declaration) and 3 (Digital Item Identification) of the norm allow respectively the full and structured specification of DI and your identification/location.

Highlighting the Part 7, Digital Item Adaptation, this standardizes the descriptors and description schemes, allowing adaptation of the contents of the users, networks, terminals or use environment.

The work of the MPEG-21 is located in perfect continuity with those made earlier in the context of MPEG-7. The corresponding descriptors and description schemes are developed under the responsibility of the MDS Group (Multimedia Description Schemes) and with the help of the same data description language based on XML.

In short, the possible interrelations between the MPEG-21 standards relating to e-learning metadata technologies are shown graphically by Lyon *et al.* in Table I [14]:

Table I presents the fields covered by the main rules of the ICTE – in vertical positioning.

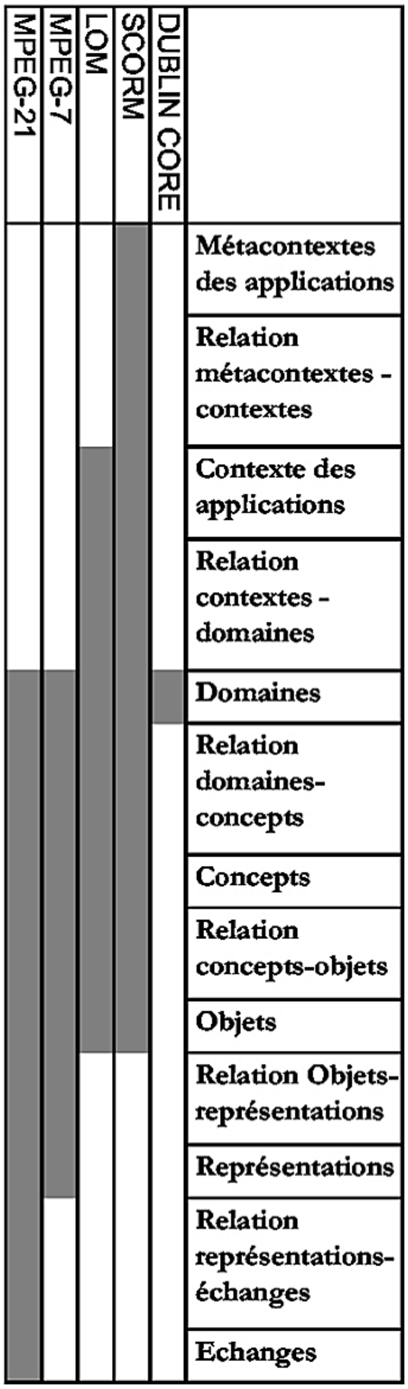


Table I–Mapping among MPEG and e-learning metadata standards [14] (vertical orientation).

The information provided by this Table I have much importance for validating the hypothesis presented in this doctorate study. In Table I, there are presented a group of ICTE metadata standards (Dublin Core, SCORM and LOM) and a group of Multimedia metadata standards (MPEG-7 and MPEG-21).

It is possible to specially verify the similarities matching MPEG-21 and SCORM metadata standards, objects of the present study. In English, the matching characteristics between both standards are:

- Domains;
- Concept-Domains relation;
- Concepts;
- Concept-Object relations;
- Objects.

Table I has an equivalent, in English, given by [15] and showed here as Table II (in p.86 of this study).

The metadata systems integration is already a longtime issue of investigation for the telecommunications community, mostly linked to Digital Television.

In [17], [18], [19] and [20], we have samples of the discussion involving MPEG-7, MPEG-21 and TV-Anytime. Even the issue of Digital TV and SCORM was initially discussed [21].

MPEG-21 became the modular development and standardization platform (a *framework*) [13] towards global integration of all multimedia documents.

The multimedia is not the product of a specific area of knowledge, but is a direct consequence of standardization of digital practices such as telecommunications, audiovisual, informatics.

Although the fact that MPEG-21 came up from a community that focuses on audio and video, the so called *MPEG-21 Framework* [12] can host all kinds of complex digital objects, such as electronic text, digital magazines, scientific data etc.

As can be seen from the scientific literature [25], [26] and [12] and from the norm itself [13], the MPEG-21 standard have a non-rigid structure of metadata, and Part 2 standard, DID, exposes the digital Item as the most generic approach for this purpose structural description of use of metadata in digital objects of all kinds.

The use of MPEG-21 DIDL (Digital Idem Declaration Language) as a generic standard for the representation, cataloging and storage of digital learning objects in the library has been proposed by [14], and applied in [15] and [16].

That could demonstrate the applicability of the DIDL for representing complex objects of any type of media or content to create a digital collection in the library.

The second key concept in MPEG-21 format is the description of the production and interaction with the media, for all stakeholders in the process, from content producer to the end user. Therefore, it can be said that the main objective of MPEG-21 is to define the technologies needed to support the exchange, access, consumption, trade or handling of Digital Items in an efficient and transparent way [12].

The orientation of the work of JTC1 SC36, as can be accompanied by paper published by IEEE [11] is based essentially on the portability, interoperability and adaptability of technologies for education, teaching and learning.

The SC36 does not, therefore, calling to extend the work carried out by other technical committees, such as the SC29 itself, the media committee, which deals with sound encoding, image, multimedia and hypermedia information.

However, the SC36 was a pioneer in pointing to the need for synergy with the SCORM MPEG-21 standard, proposition however limited to addressing issues of copyright and eventually the e-commerce of ICTE (Part 5 of the standard).

The MPEG-21 normalization lies in perfect continuity with the ones previously carried out within the *MPEG-7 framework*. And many MPEG-7 standard descriptors are part of the MPEG-21 metadata schema [12] scope.

The descriptors and corresponding description schemes are developed under the responsibility of MDS group, whose data description is founded on the semantics of XML markup language.

The interrelationships between MPEG and e-Learning metadata standards are outlined in Table I [14] and in Table II [15]:

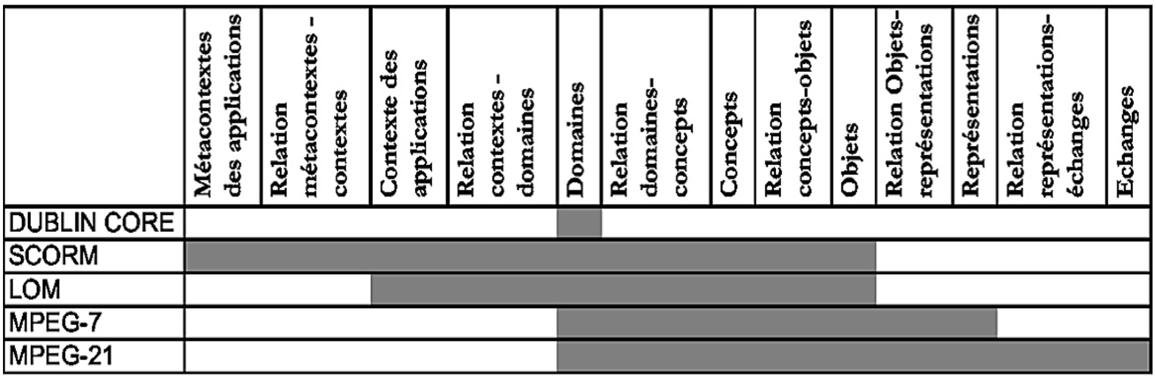


Table I–Mapping among MPEG and e-learning metadata standards [14] (horizontal orientation).

In Table I it is shown the relation among three important e-learning metadata standards (DCMI Dublin Core, SCORM and LOM) and their relations to the multimedia metadata standards approached in this research (MPEG-7 and MPEG-21 formats).

Table II refers to a former academic study relating SCORM and MPEG-7 learning objects standards comparing their characteristics, as shown in details in the table:

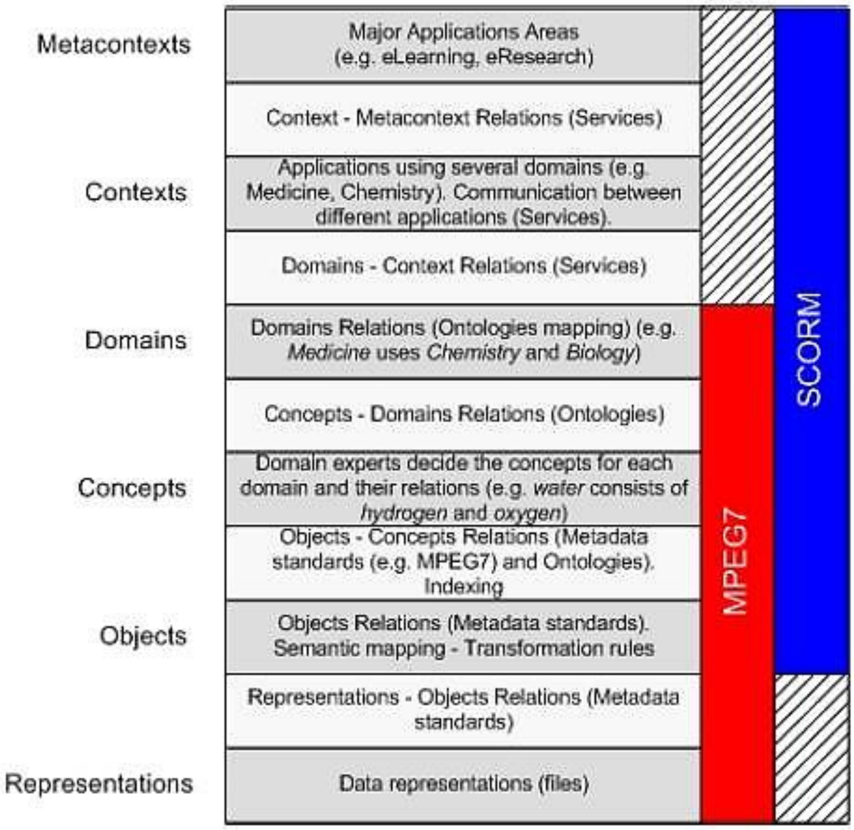


Table II–Mapping between MPEG-7 and SCORM [15].

In this Table II, it can be seen that the properties of Domains relations (directly referring to Ontologies mapping), the Ontologies themselves (Concept-Domains relations), the Objects relations and the Representations are equivalent formatted in both standards.

MPEG-21, in its turn, comprehends in its structure the MPEG-7 metadata, adding further features, so the knowledge done by [15] study is very important to assure that an Ontology designed around MPEG-21 and SCORM is feasible and actually necessary to be done.

5.3 LEARNING OBJECTS AND METADATA STANDARDS

A Learning Object can be defined, in a perspective of Engineering, according to IEEE 1484.12.1 standard (Standard for Learning Object Metadata) [11], “For this standard, a learning object is defined as any entity, digital or non-digital, that may be used for learning, education, or training”.

According to the IEEE LTSC [11], the LOM standard focus on the minimum attributes needed to allow a learning object to be found and evaluated. Metadata allow the cataloging and coding of the objects to turn them comprehensible within most e-learning platforms.

For instance, SCORM doesn’t define itself a metadata model – it recognizes the LOM standard as the standard in fact [10]. Yet, SCORM defines XML as the syntax for metadata representation (process called *XML binding*). That is the reason why the LOM standard is used for represented metadata on SCORM mapped elements on this research.

Actually, the standard SCORM 2014, or SCORM 1.4, presents 3 Parts (or sub-specifications) [27]:

- Content Packaging Model (CAM) section: specifies how content should be packaged and described. It is based primarily on XML.
- Run-Time Environment section (RTE): specifies how content should be launched and how it communicates with the LMS. It is based primarily on ECMAScript (JavaScript).
- Sequencing Navigation (SN) section: specifies how the learner can navigate between parts of the course (SCOs). It is defined by a set of rules and attributes written in XML.

Within its CAM model published by ADL [10], SCORM defined in its part related to Metadata nine categories to describe learning objects attributes. The definition must be applied to assets, SCO (groups of assets), activities, content organizations and content aggregations, for their identification, categorization, consult and findability, to facilitate sharing and reusability.

```
<?xml version="1.0" encoding="UTF-8" ?>
<lom xmlns="http://ltsc.ieee.org/xsd/LOMv1p0"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:schemaLocation="http://ltsc.ieee.org/xsd/LOMv1p0
                         http://www.rdn.ac.uk/oai/lom/lom.xsd">

  <general>
    <title>
      <string>developerWorks : XML</string>
    </title>
    <description>
      <string>
        The XML zone on the developerWorks Web site is designed for
        developers. You'll find tools, samples, standards
information,
        education, news and events, and links to XML community forums
        and Web sites.
      </string>
    </description>
    <!-- Many other keywords snipped -->
    <keyword>
      <string>xml resources</string>
    </keyword>
    <keyword>
      <string>xml programming</string>
    </keyword>
  </general>
  <lifeCycle>
  </lifeCycle>
  <technical>
    <format>text/html</format>
    <location>http://www-106.ibm.com/developerworks/xml/</location>
  </technical>
  <educational>
    <learningResourceType>
      <source>DCMIType</source>
      <value>Text</value>
    </learningResourceType>
  </educational>
</lom>
```

Figure 5–SCORM metadata file structure [10].

As a title of example, by presenting a chart of SCORM metadata XML coding in Figure 5 its structure can be better comprehended:

There we can notice that LOM standard “<lom>” tags in XML language as evidence of the metadata classified for a given learning object as a general example.

PART 3 – IMPLEMENTATION AND APPLICATION

6. ONTOLOGY INTEGRATING MPEG-21 AND SCORM: FUNDAMENTALS

6.1 THE ONTOLOGY FUNDAMENTALS

According to T. Gruber, Ontology is a “formal, explicit specification of a shared conceptualization” [39]. A specification consisting of:

- Classes.
- Relations between classes.
- Individuals.
- Axioms.

This implies that ontologies provide a shared formal common language for modeling features from a domain of discourse.

Ontologies are used to logically represent concepts and the relationships that make up the concepts. In learning technologies, ontologies are important because they have the potential to be used, in combination with metadata representations, particularly RDF representations (RDF Statements can be used with MPEG-21 DIDL metadata, besides W3C OWL Web Semantics language), so that intelligent data systems can apply logic and rule-based reasoning to learning objects. RDF, or Resource Description Framework, is a family of the W3C specifications originally designed as a metadata data model.

Systems that share the same ontology are able to communicate about a domain of discourse without necessarily operating on a globally shared theory.

> In 1997, Borst defined an Ontology as a formal specification of a shared conceptualization. This definition additionally required that the conceptualization should express a shared view between several parties, a consensus rather than an individual view [29 apud 28].

And completing the classical definition of ontology, “In 1998, Studer et al. merged these two definitions stating that: An ontology is a formal, explicit specification of a shared conceptualization [30 apud 28]”.

Ontology stands for a definition of classes of objects, attributes, properties and relations to other objects, roughly speaking. An ontology is a collection of concepts and relations among them, based on the principles of classes, identified by categories, properties that are different aspects of the class and instances that represents the objects.

In Science and Information Technology, ontologies are classifications. They are used as a means for categorizing and grouping the information into classes.

Ontologies are also applied in areas of Computer Engineering, like Semantic Web and Artificial Intelligence, to assimilate and codify knowledge, defining the relationship among the concepts of a particular domain (which constitutes an area of knowledge). Far beyond being only a hierarchic classification and relations among classes of knowledge, ontologies are useful for developing intelligent tutor systems.

Ontologies also have been proposed as a general tool to help to overcome problems in AI and education [30].

As defined by Borst [29],

> an Ontology is a formal explicit description of a domain, consisting of classes, which are the concepts found in the domain (also called entities). Each class may have one or more parent classes (is-a or inheritance links), formulating thus a specialization or generalization hierarchy.

An ontology compartmentalizes the variables needed for some set of computations and establishes the relationships between them [28], [29].

Like XML language, an Ontology relates to OOP, since it is based on hierarchically structured classes and subclasses, defines classes properties and attributes, as well as it allows creating individual instances of classes within the hierarchy.

Ontologies can be represented or in a graphical format, as well as in table format.

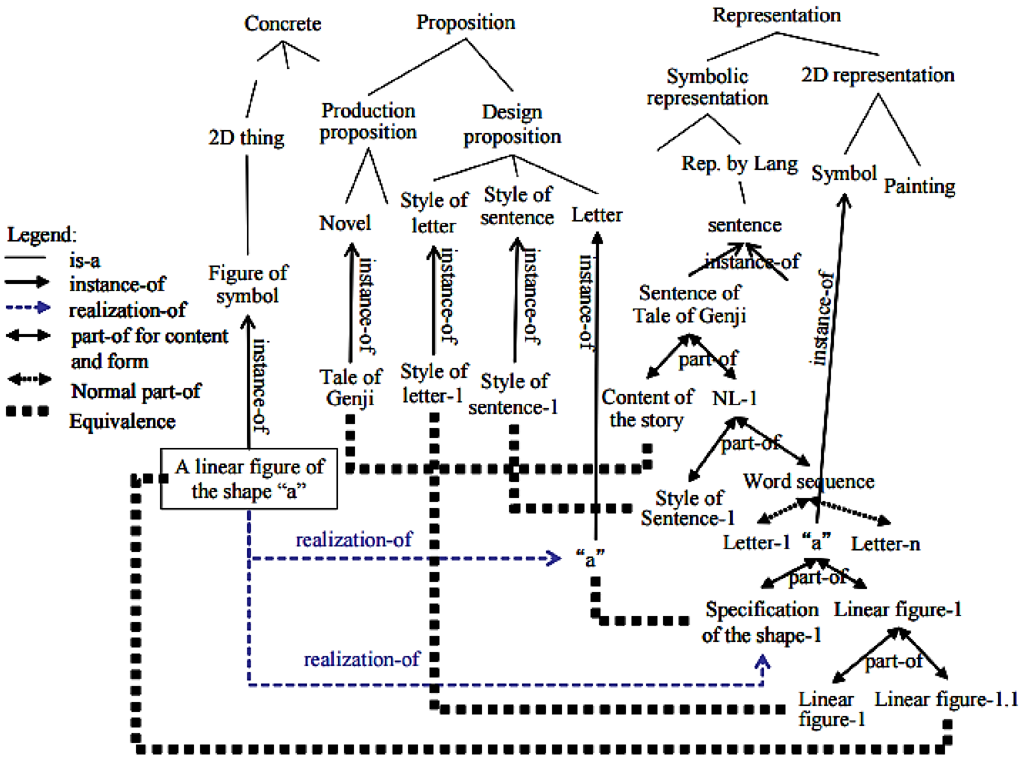


Figure 6–Example of graphical Ontology [32].

The graphical format is structured on propositions relating concepts, like in a conceptual map, highlighting interdependent classes, slots and attributes.

Ullrich [31] propose the use of pedagogical ontologies:

Figure 7–Pedagogical Ontology [31].

Tables III and IV [31] presents an Ontology represented in form of chart, an overview of the proposed ontology upper level classes and Figure 7 the class hierarchy of the ontology as displayed in software *Protégé*.

Class Name	Class Description
Person	Basic User Information like name, date of birth, e-mail
Characteristic	General user characteristics, like eye color, height, weight, etc.
Ability	User abilities and disabilities, both mental and physical
Living Conditions	Information relevant to the user's place of residence and house type.
Contact	Other persons, with whom the person is related, including relatives, friends, co-workers.
Preference	User preferences, for example "loves cats", "likes blue color" or "dislikes classical music"
Interest	User hobby or work-related interests. For example, "interested in sports", "interested in cooking"
Activity	User activities, hobby or work related. For example, "collects stamps" or "investigates the 4^{th} Crusade"
Education	User education issues, including for example university diplomas and languages
Profession	The user's profession
Expertise	Includes all kinds of expertise, like computer expertise
Thing	Living things or Non Living Things the user may posses or otherwise be related to, like a car, a house, a book or a pet

Table III– User profile ontology exemplified [31].

Interest hierarchy	"Interest" Instances (Type, Name)
Business	(<Root>, Business)
Investing	(Business, Investing)
Stocks & Bonds	(Investing, Stocks & Bonds)
Sports	(<Root>, Sports)
Basketball	(Sports, Basketball)
Professional	(Basketball, Professional)
College & University	(Basketball, College & University)

Table IV– Example of modeling a hierarchy within an ontology [31].

Dolog [33] proposes an architecture for distributed e-learning environments based on semantic web technologies. They describe three different ontologies to undertake the adaptation features: one for describing learning resources, one for describing domain information and another for describing learners with respect to user interests, performance, goals, preferences and so on. None of these represent the instructional function of a resource.

6.1 THE XPATH LANGUAGE

The intended Ontology for integrating SCORM and MPEG-21 metadata formats can be carried out by matching their syntax correspondences, through the W3C *XML Path Language* – XPath.

> The XML Information Set (Infoset) defines a data model for XML. This data model is a set of abstractions that detail the properties of XML trees. These abstractions provide a common viewpoint from which to think about XML APIs and higher-level specifications such as XPath, XSLT and XML Schema [37].

The citation can be demonstrated as shown in Figure 8:

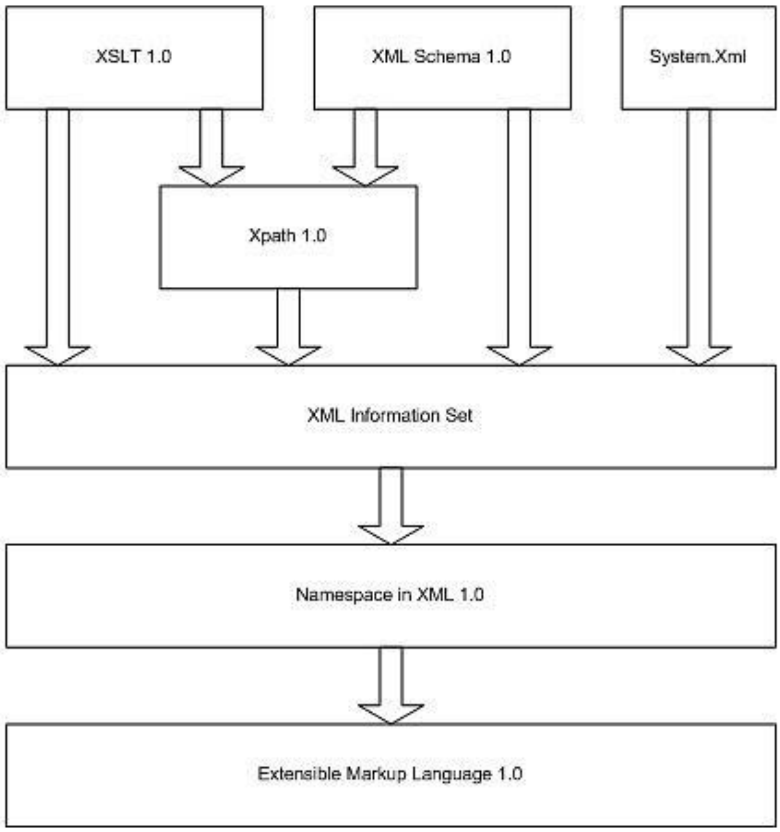


Figure 8– XML abstractions [37].

The concept of the XPath syntax is the location path. XPath is UNIX path-like, therefore a *non-XML* syntax, for addressing (*e.g.* to indicate or select) fragments of an XML document, such as a group of elements, an individual element, an element with an specific attribute, an element with a particular parent, and so on.

> In XPath parlance, the information items of the XML Infoset are called nodes. XPath expressions are used to specify nodes by name, by node type, by absolute or relative position within the document structure (hierarchy), by the strings elements contain, and much more. (...) XML Schema uses XPath to define constraints [37, p.583].

There are some key features regarding XPath language which were strongly considered on the decision for this proposed methodology [34]:

- XPath is a syntax for defining parts of an XML document
- XPath uses path expressions to navigate XML documents
- XPath contains a library of standard functions
- XPath is a major element in XSLT[14]
- XPath is a W3C recommendation

XPath is a language maintained by the W3C with the primary objective of addressing parts of an XML document, and it is also used to test whether a code matches a pattern, or another code.

It is well known that XPath specification currently has got the status of Recommendation, what means it is ready to be implemented and will not change its status in this version.

---

[14] XSL stands for EXtensible Stylesheet Language (and it is applied on XML files).

Thus stated, XPath syntax can be used to select or consult fragments of information within XML files in some particular practices following described.

XPath syntax is very similar to those used to traverse file systems or other hierarchical structures [36]. Its node-based tree model follows the [parent] / [children] model of the Infoset.

Location paths can be partitioned into *location steps*, separated by the pattern *forward slashes*. Each location step consists of three parts: an axis identifier, a note test and zero or more predicates. The general form is as follows [36, p.107]:

axis-identifier::*node-test*[*predicate1*][*predicate2*]

We can infer the axis identifier is separated from the node test, as well as the predicates expressions are enclosed within square brackets.

In its turn, Figure 9 shows the decomposition of an XPath expression and its constituent location steps.

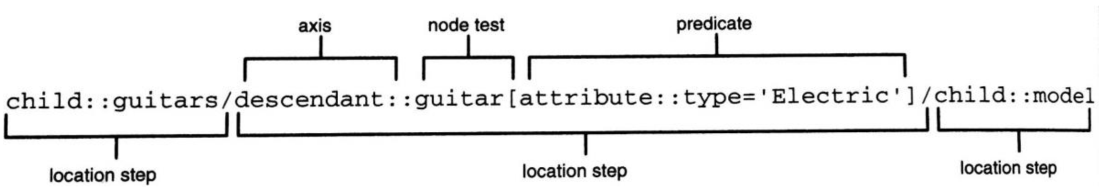


Figure 9– Location path and location step parts [36, p.108].

6.1.1 XPath – Expression

A designated *XPath expression* defines a pattern in order to select a set of nodes.

These patterns are used by XSLT[15] to perform transformations or by XPointer[16] for addressing of fragments purpose (XSLT and XPointer are two of the XPath language extensions).

XPath specification defines seven types of nodes. These nodes constitute the output of execution of the XPath expression.

These seven path node types defined within the XPath expression are:

- Root
- Element
- Text
- Attribute
- Comment
- Processing Instruction
- Namespace

The XPath path nodes are further discussed in the item 6.1.3.

Figure 10 [36, p.104] represents the XPath information model, essentially based on the tree hierarchical structure. The example contains all seven path nodes defined by XPath Expression, as follows:

---

[15] XSLT stands for XSL Transformations.
[16] XML Pointer Language, which is based on the XML Path Language (XPath), supports addressing into the internal structures of XML documents.

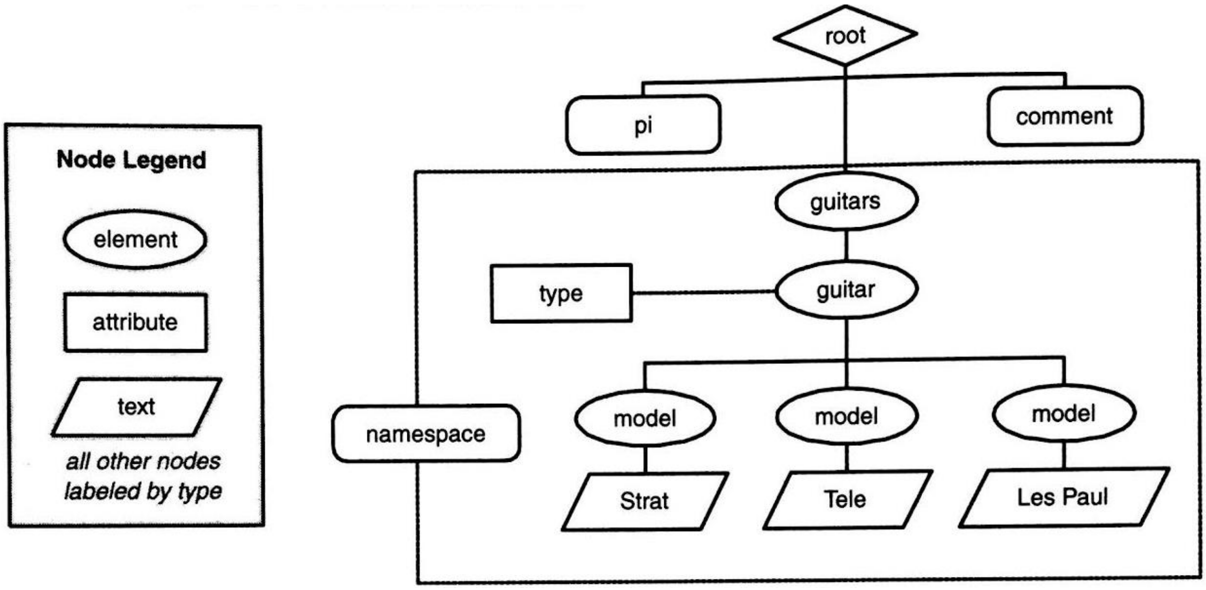


Figure 10–XPath information model [36, p.104].

It is noticeable that the root node has three children nodes:

- A Processing Instruction node (“pi”).
- An Element node (“guitars”).
- A Comment node (“comment”).

Guitars node, in its turn, contains a Namespace node (“namespace”, which represents an environment container). Namespaces are used to disambiguate the names of element and attribute information items.

According to the legend, the same logic is applicable for the comprehension of the further nodes (labeled by type: Element, Attribute and Text nodes).

As a native functionality, XPath uses a path expression to select node or a list of nodes from an XML document.

Following is the list of useful paths and expressions to select any node or list of nodes from a given XML document:

S.No.	Expression & Description
1	**node-name** Select all nodes with the given name "nodename"
2	**/** Selection starts from the root node
3	**//** Selection starts from the current node that match the
4	**.** Selects the current node
5	**..** Selects the parent of the current node
6	@ Selects attributes
7	**computer** Example − Selects all nodes with the name "computer"
8	**/network/computer** Example − Selects all computer elements that are children of
9	**//computer** Selects all computer elements no matter where they are in

Table V–XPath Expressions.

6.1.2 XPath Predicate

Predicate refers to the XPath expression written in square brackets. It refers to restrict the selected nodes in a node set for some condition.

Predicates can be used for searching elements and its values within an XML coded file, like a multimedia MPEG-21 file.

An example with multiple (two) predicates is:

Item[@type=”value”][5]

Notice that there are pointed two predicates, within square brackets, which represent the selection of the fourth Item element that has a type attribute (“@”) with the value “produce”.

If it is wanted to ask for all person elements that have a profession child element with the value "PhD," it would be used the XPath expression //person[profession="PhD"]. If it is wanted to find the person element with id m1234, it is put an @ in front of the name of the attribute as in //person[@id="m1234"].

A chart demonstrating the four predicate fundamentals is shown in Table VI:

S.No.	Predicate & Description
1	**/network/computer[1]** Select first computer element which is child of the network element.
2	**/network/computer[last()]** Select last computer element which is child of the network element.
3	**/network/computer[@acquisition=2016]** Select computer element with the attribute acquisition year equals 2016.
4	**/network/computer[id>10]** Select computer element with the attribute id > 10 within the network.

Table VI–XPath Predicates.

6.1.3 XPath Nodes

There are seven Path Nodes Types that can be part of an XPath tree, Nodes related to XPath expressions used to cover the corresponding Infoset that XPath defines and handles, pointed in Table VII:

S.No.	Node Type & Infoset Information Item
1	**Root** Root element node of an XML Document.
2	**Element** Element node.
3	**Text** Text of an element node.
4	**Attribute** Attribute of an element node.
5	**Comment Node** Comment information item.
6	**Processing Instruction Node** Processing instruction information item.
7	**Namespace Node** Namespace information item.

Table VII–XPath Nodes.

Highlighting the following types of nodes:

Element Node

There are multiple ways to get and handle elements.

/network/* − select all element under root node.

The selection expression can be represented as:

```
<xsl:for-each select = "/class/*">
```

/network/computer − select all computer element under root node.

```
<xsl:for-each select = "/network/computer">
```

//computer − select all computer elements in the document.

```
<xsl:for-each select = "//computer">
```

Attribute Node

As a title of example, for selecting an attribute node from an element node, this attribute can be specified in XPath expressions by putting a “@” character in front of its the name. For example:

order/@OrderNumber

An attribute can be easily retrieved and checked by using the @attribute-name of the element.

@name − get the value of attribute "name". The selection expression can be represented as:

```
<td><xsl:value-of select = "@acquisition"/></td>
```

Attributes can be used to compare using operators.

@acquisition=2016 : get the text value of attribute "acquisition" and compare with a value. The select expression can be represented as:

<xsl:if test = "@acquisition = 2016">

Fragment Oriented Syntax

XPath language is used for addressing fragments of an XML document. A document fragment is defined by this XPath specification as a balanced subset from the original document. A balanced subset means it contains whole information items, presenting whole tags – opening and closing tags.

The most common example is setting and transmitting only elements necessaries to the receiver's application.

To better comprehend what parts of a document are able to become fragments, the diagram represented in Figure 11 can exemplify this issue:

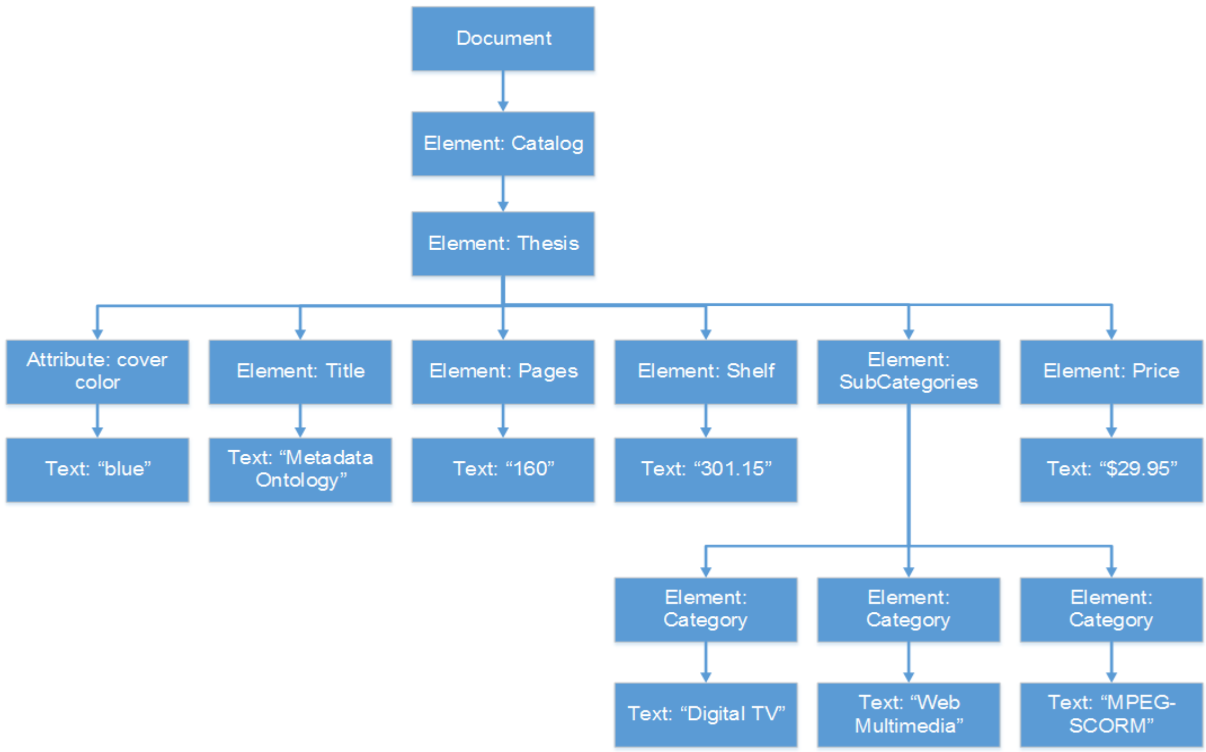


Figure 11–XML schema for a media document. Source: own authorship.

Within the representation based on the tree-model format, any of the branches connected to the main tree by a solid line can become a fragment, because it is guaranteed that each branch will be contiguously defined into the original document.

Attributes defined inside tags cannot be considered fragments, because they will not be qualified as balanced.

The practical applications of this “fragment oriented” syntax are their use on software development, like:

- Using fragments can help to save system resources (processing time, memory, storage or network requirements, and so on).
- Using fragments to isolate relevant subsets of information from a source file – since this information is contiguous (noncontiguous information cannot be sent within a single fragment).
- Using fragments to allow creating an editing environment to larger XML files.

This considered, in this research the use of XPath language is directed to carry out the comparative study of mapping between the standards of SCORM metadata and MPEG-21, applying this methodology.

Acknowledging that XPath syntax can be used to select or consult fragments of information within XML files, whether they are formatted in SCORM or in MPEG-21 schema.

6.2 THE MPEG-21 SCHEMA

As pointed in chapter 5.2, the MPEG-21 Digital Item supports perfectly this format of resource, as Figure 4 shows (figure already shown in p.69):

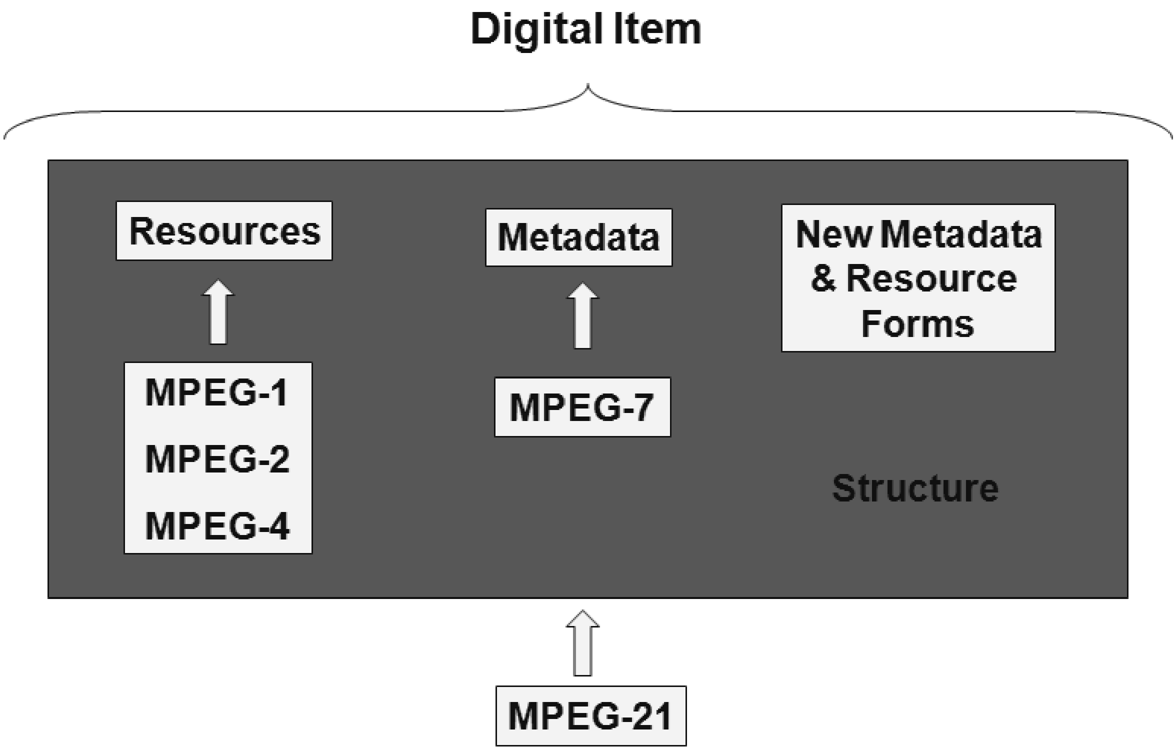


Figure 4–MPEG-21 Digital Item structure.

DIDL documents are actually XML 1.0 documents. The DIDL syntax is based on an abstract structure defined in the *Digital Item Declaration Model*.

This model defines the DIDL elements, namely: *Container; Item, Component, Anchor, Descriptor, Choice, Selection, Condition, Annotation, Assertion, Resource, and Statement*. Thus structurally represented in Figures 12 and 13:

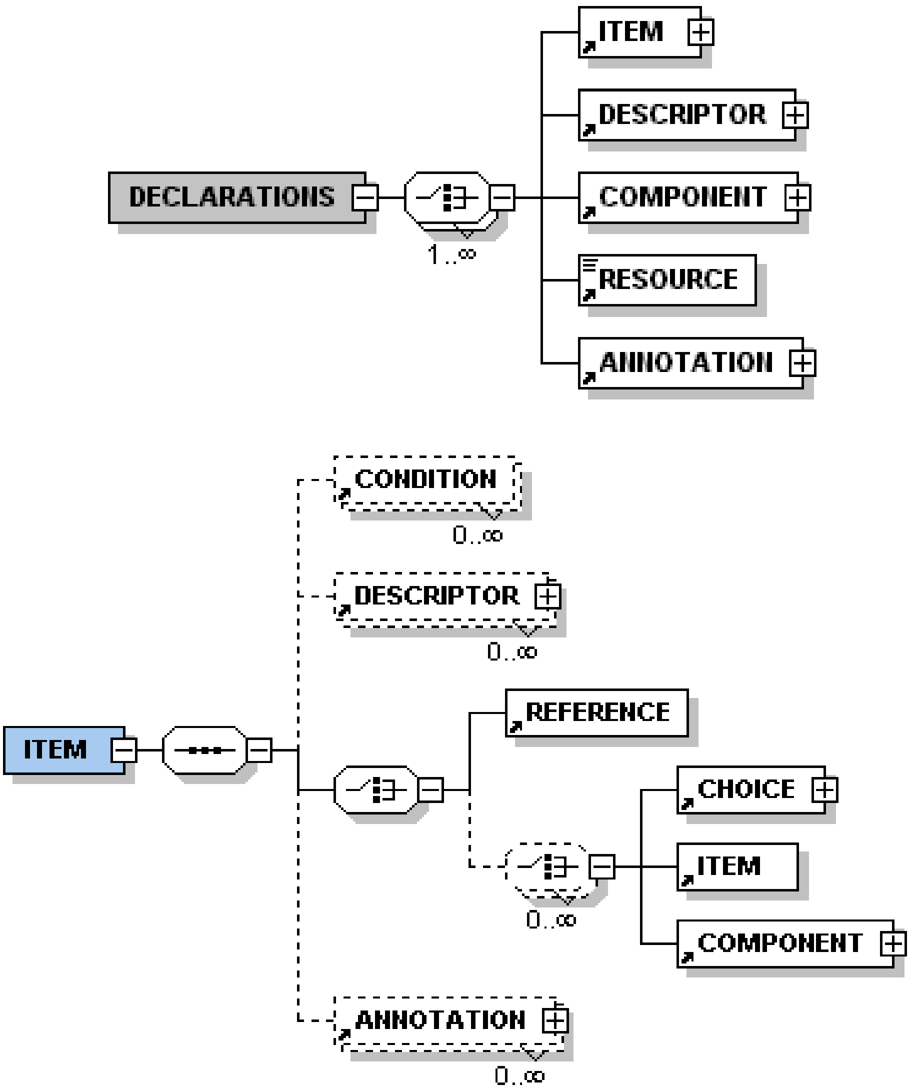


Figure 12–Partial graphical representation of DIDL schema [12], highlighting the Declarations and Item elements.

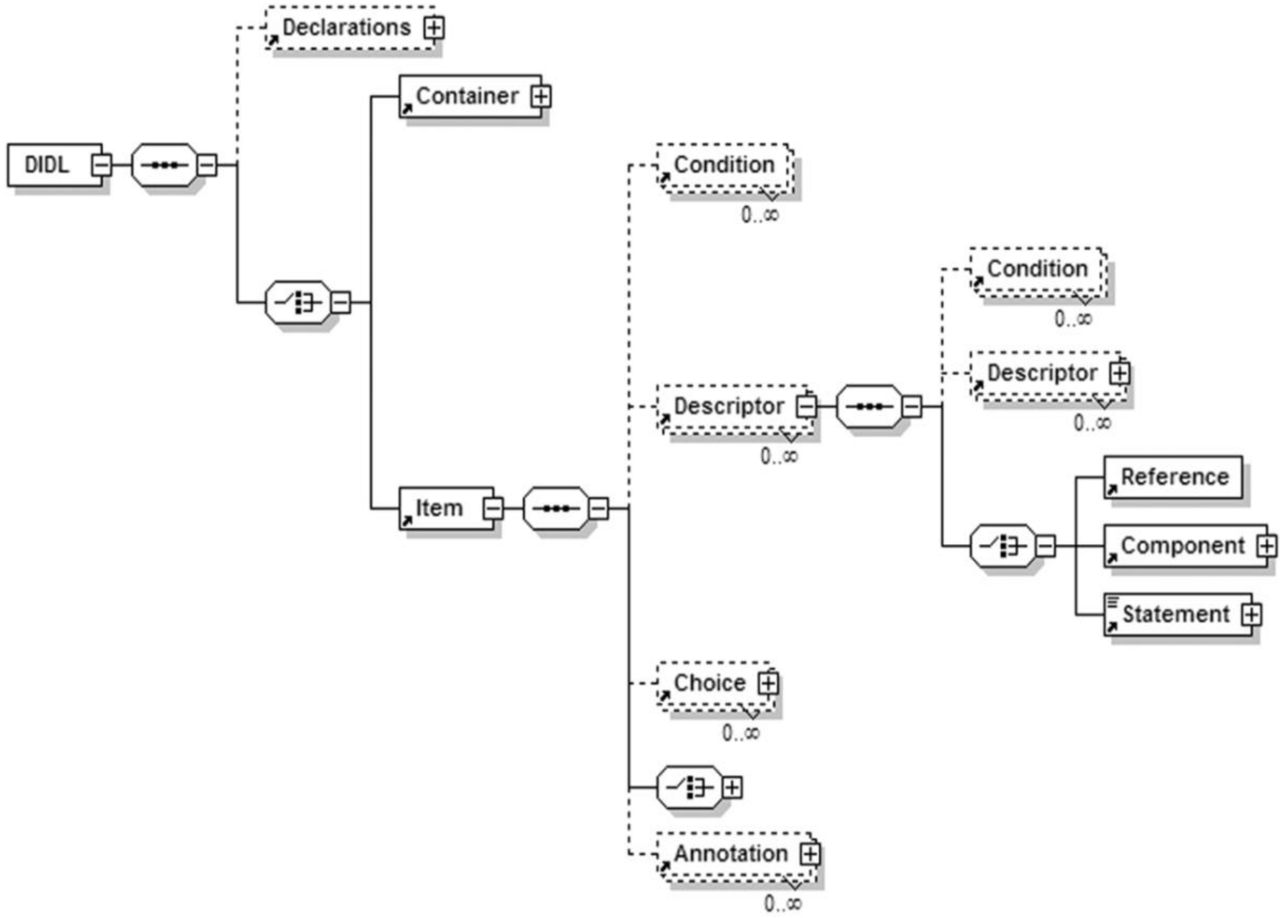


Figure 13–Partial graphical representation of the DIDL schema generalized from the ISO/IEC norm 21000-2:2003 [12].

The DIDL XML code for *Declarations* element (a special element that defines a selection of elements without instantiate them) would be displayed in the following generic form [12]:

```
<xsd:element name="DECLARATIONS">
  <xsd:complexType>
     <xsd:choice maxOccurs="unbounded">
        <xsd:element ref="ITEM"/>
        <xsd:element ref="DESCRIPTOR"/>
             <xsd:element ref="COMPONENT"/>
             <xsd:element ref="RESOURCE"/>
          <xsd:element ref="ANNOTATION"/>
```

</xsd:choice>

</xsd:complexType>

</xsd:element>

We can equally comprehend the MPEG-21 formatted media file as a DID structure composed by preexistent MPEG-7 and new MPEG-21 metadata, associated to media resources (the media files).

This way, they compose a hierarchical metadata structure within an expected MPEG-21 general purpose file in its complete structure, as shown on Figure 14:

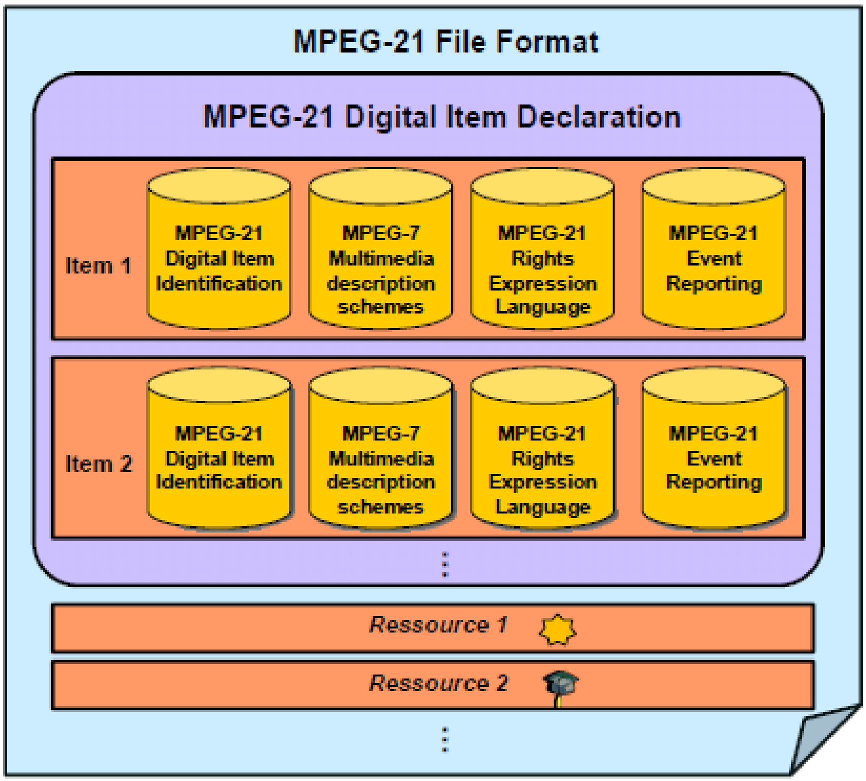


Figure 14–Hierarchical metadata structure within an expected MPEG-21 general purpose file in its complete structure [26].

A workflow exemplifying the metadata representation of a media like a digital music album, in the MPEG-21 standard, can be represented as designed on Figure 15:

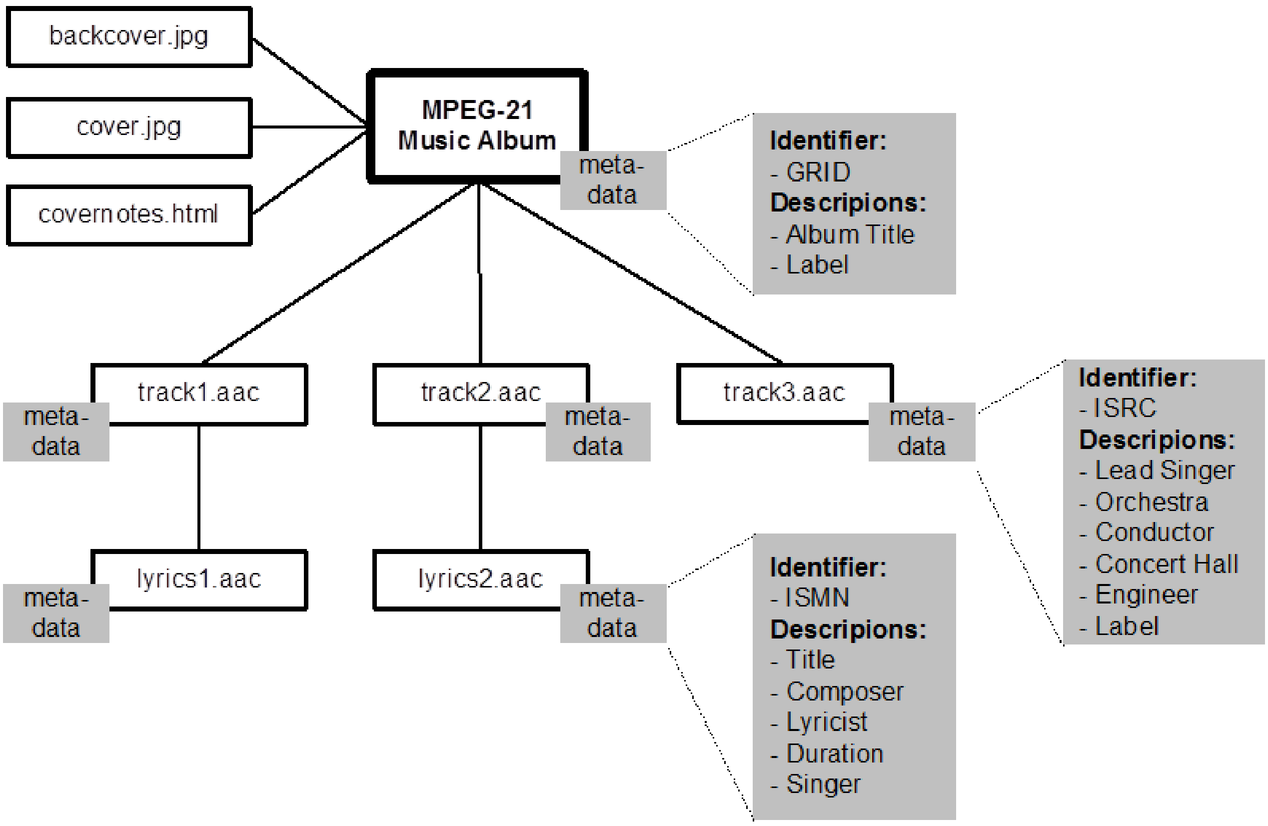


Figure 15–MPEG-21 metadata representation of a descripted media – a digital music album [12].

As we can infer from Figure 15, there are key elements like the identifiers and the descriptors, whose coding is mandatory for representing data aspects of each subpart of the hereby exemplified digital media.

A codename is attributed to an Identifier, which contains a set of Descriptions, or Descriptor, composing its particular metadata.

We can also identify the different resource formats used to compose this media or library item (a music album actually) described through the MPEG-21 metadata standard.

There were used still images assets like *JPG* files, *AAC* audio tracks and even an *HTML* hyperdocument. Each file receives its own set of metadata, represented by the Identifiers and Descriptions. As well as the general MPEG-21 file container has its set of metadata and also its support files that characterizes this source.

6.3 THE SCORM SCHEMA

It can clearly be delineated a parallel between MPEG-21 schema and SCORM schema. Both are composed on a very similar triadic structure.

As it could be seen in MPEG-21 schema, it is composed by:

- Metadata.
- Resources.
- Structure

Within SCORM schema, the composition for the Manifest file is exactly [10], as we can notice in Figure 16:

- Metadata.
- Resources.
- Organizations.

The definition of “Organizations”, in SCORM, is basically the same as the “Structure”, for the MPEG-21.

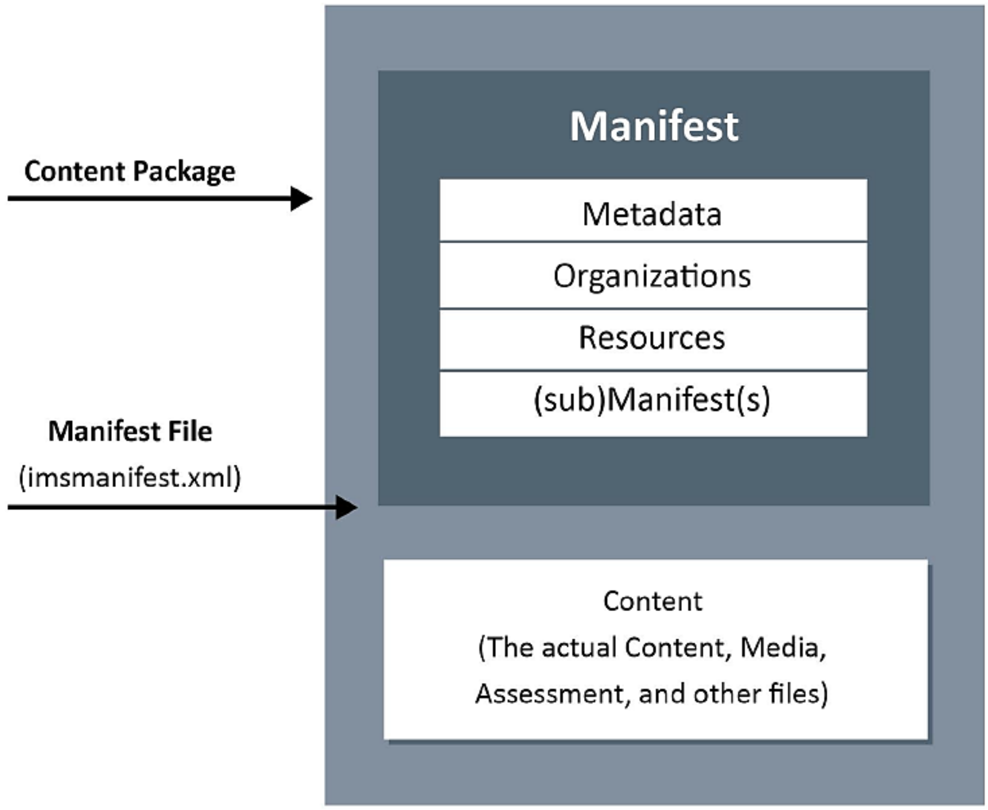


Figure 16–SCORM learning object [10].

The Manifest is the only mandatory file within a SCORM package. Its name must be imsmanifest.xml and is supposed to be placed into the package's root folder. The manifest presents three essential parts:

- Metadata, the metadata containers or a reference to them, in a complementary file.
- Organizations or sequence of presentation, declaring the organizational structure, the sequence of HTML pages presentation, as well as the user navigation controls.
- Resources, the list indexing the individual assets ("files") composing the package.

It is clear from an analysis of the metadata package in practice that the SCORM Manifest contains the metadata tag "<metadata>", the organization tag "<organizations>" and the resource tag "<resources>" exactly as the schematic representation diagram in the SCORM package, as seen in Figure 17.

```
<metadata>
  <schema>ADL SCORM</schema>
  <schemaversion>2004 4th Edition</schemaversion>
</metadata>
<organizations default="ORG-4BF8CA544F0C5AB2D67407854D8EB322">
  <organization identifier="ORG-4BF8CA544F0C5AB2D67407854D8EB322" structure="hierarchical">
    <title>Ligações químicas</title>
    <item identifier="ITEM-B4654588FC70AE58CA00E26C17FC1A5E" identifierref="resource-covalent" isvisible="true">
      <title>Item</title>
    </item>
  </organization>
</organizations>
<resources>
  <resource identifier="resource-covalent" adlcp:scormType="asset" href="covalent.html" type="webcontent">
    <file href="covalent.html" />
  </resource>
```

Figure 17-SCORM Manifest [10].

SCORM doesn't define itself a metadata model to be followed. Instead, it recognizes LOM as the *de facto* standard and strongly recommends LOM (ADL, 2004, p. 4-65). However, SCORM does define XML as language used for the representational metadata (which is called *XML Binding*).

SCORM is developed by technologists implementing their own philosophy, OOP paradigm, UML (designed for relatively simple objects) and available technologies to support wide variety of learning/instructional use cases and best practices.

The metadata defined in this section is directly based on the IEEE 1484.12.1-2002 Learning Object Metadata (LOM) [11] standard and the IEEE 1484.12.3 standard for Extensible Markup Language (XML) Binding for Learning Object Metadata data model [38]. The IEEE provides roughly 64 metadata elements that can be used to describe SCORM Content Model Components. SCORM strongly recommends the use of the IEEE LOM for describing SCORM Content Model Components.

Actually, the standard SCORM 2014, version 1.4, presents 3 Parts (or sub-specifications) [27]:

- Content Packaging Model (CAM) section: specifies how content should be packaged and described. It is based primarily on XML.
- Run-Time Environment (RTE) section: specifies how content should be launched and how it communicates with the LMS. It is based primarily on ECMAScript (JavaScript).
- Sequencing Navigation (SN) section: specifies how the learner can navigate between parts of the course (SCOs). It is defined by a set of rules and attributes written in XML.

Within its CAM section published by ADL [10], SCORM defined in its part related to Metadata nine categories to describe learning objects attributes. The definition must be applied to assets, SCO (groups of assets), activities, content organizations and content aggregations, for their identification, categorization, consult and findability, to facilitate sharing and reusability.

This section provides specific requirements and guidance for using metadata to describe SCORM Content Model Components.

Data Type: the <lom> tag element is a parent element. Parent elements have no values associated with them. Parent elements act as “containers” for other elements.

The <lom> element contains those metadata nine categories, as the following child elements:

- <general>
- <lifeCycle>
- <metaMetadata>
- <technical>
- <educational>

- <rights>
- <relation>
- <annotation>
- <classification>

The nine categories of metadata elements are:

1. The General category can be used to describe general information about the SCORM Content Model Component as a whole.
2. The Life Cycle category can be used to describe features related to the history and current state of the SCORM Content Model Component and those who have affected the component during its evolution.
3. The Meta-metadata category can be used to describe information about the metadata record itself (rather than the SCORM Content Model Component that the record describes).
4. The Technical category can be used to describe technical requirements and characteristics of the SCORM Content Model Components.
5. The Educational category can be used to describe the educational and pedagogic characteristics of the SCORM Content Model Component.
6. The Rights category can be used to describe the intellectual property rights and conditions of use for the SCORM Content Model Component.
7. The Relation category can be used to describe features that define the relationship between this SCORM Content Model Component and other targeted components.

8. The Annotation category can be used to provide comments on the educational use of the SCORM Content Model Component and information on when and by whom the comments were created.
9. The Classification category can be used to describe where the SCORM Content Model Component falls within a particular classification system.

Example:

This example is used to illustrate the concepts described above.

The nine category elements are represented as empty elements for simplicity.

```
<lom xmlns="http://ltsc.ieee.org/xsd/LOM">
<general/>
<classification/>
<annotation/>
<lifeCycle/>
<technical/>
<metaMetadata/>
<educational/>
<relation/>
<rights/>
</lom>
```

The SCORM ontology, represented as a hierarchical structure composed by nine categories of metadata elements, can be represented as follows:

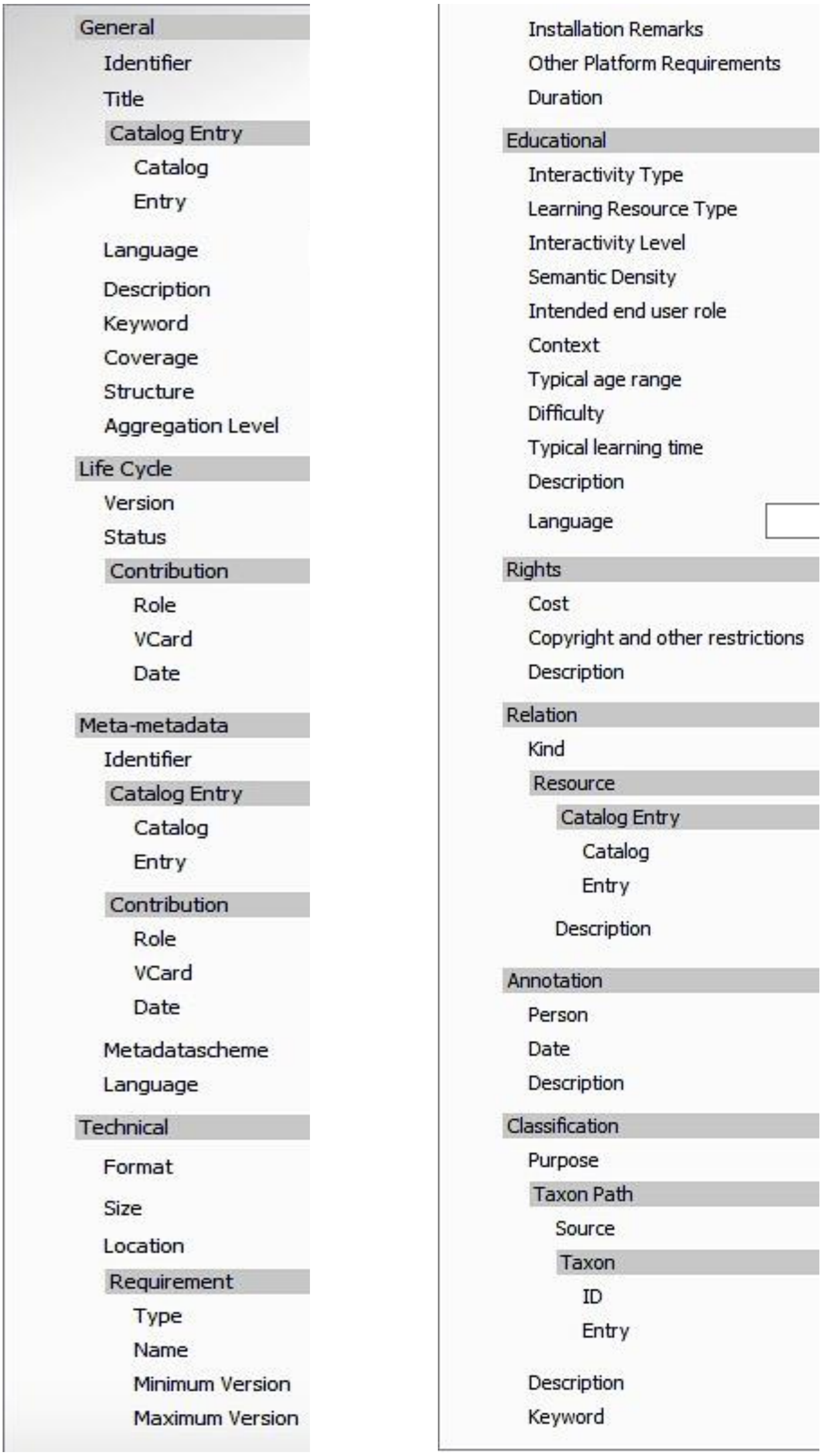


Figure 18–SCORM Ontology.

Its description, in details, is specified by the following technical table as a SCORM 2004 Metadata Structure:

- **<lom>** [1]Root level element that contains a metadata instance describing a learning object.
  - **<general>** [0:1]Container element for general metadata.
  - **<lifeCycle>** [0:1]Container element for metadata describing the history and current state of the learning object.
  - **<metaMetadata>** [0:1]The metaMetadata container element provides for metadata about the metadata itself.
  - **<technical>** [0:1]Container element containing information about the technical implementation of this learning object.
  - **<educational>** [0:1]The educational container element holds information about the educational or pedagogic characteristics of the learning object.
  - **<rights>** [0:1]The rights container element holds information about the intellectual property rights associated with this learning object.
  - **<relation>** [0:many]The relation category describes this learning object's relationship with other components.
  - **<annotation>** [0:many]The annotation container provides a way for authors to make additional comments on the educational use of this learning object.
  - **<classification>** [0:1]The classification container element is used to categorize this learning object within the context of a controlled vocabulary or classification system.

Figure 19–SCORM 2004 Metadata Structure [42].

Its subcategories used in this research are expanded in the following Figure 20:

- **<lom>** [1]Root level element that contains a metadata instance describing a learning object.
  - **<general>** [0:1]Container element for general metadata.
    - **<identifier>** [0:many]Container element for a value that identifies this learning object.
      - **<catalog>** [0:1]Cataloging scheme (or scope) in which the learning object is being identified (URI, ISBN, ISSN, etc).
      - **<entry>** [0:1]Identifier of the learning object that is unique within the catalog.
    - **<title>** [0:1]Title of the course
    - **<language>** [0:many]The language(s) this learning object uses to communicate with the learner.
    - **<description>** [0:many]A textual description of the learning object.
    - **<keyword>** [0:many]One or more keywords describing the learning object. Each keyword entry may contain more than one word if the entry represents a phrase.
    - **<coverage>** [0:many]Describes the scope (time, culture, geography, region, etc) of the training in the learning object.
    - **<structure>** [0:1]Describes the organizational structure of the content. (atomic, collection, networked, hierarchical, linear)
    - **<aggregationLevel>** [0:1]Functional granularity of the learning object (1=smallest level of granularity [raw asset], 4=highest level of granularity [complete course])
  - **<lifeCycle>** [0:1]Container element for metadata describing the history and current state of the learning object.
    - **<version>** [0:1]Current version of the learning object.
    - **<status>** [0:1]Current status of the learning object (draft, final, revised, unavailable)
    - **<contribute>** [0:many]Provides a list of entities (people, companies, etc) that have contributed to the creation of this learning object.
      - **<role>** [0:1]The type of contribution made (author, publisher, unknown, initiator, terminator, validator, editor, graphical designer, technical implementer, content provider, technical validator, educational validator, script writer, instructional designer, subject matter expert).
      - **<entity>** [0:many]VCard identifying the entity making the contribution.
      - **<date>** [0:1]Timestamp of the contribution
  - **<metaMetadata>** [0:1]The metaMetadata container element provides for metadata about the metadata itself.
  - **<technical>** [0:1]Container element containing information about the technical implementation of this learning object.
    - **<format>** [0:many]MIME types of the content used in this learning object.
    - **<size>** [0:1]Size in bytes of this learning object.
    - **<location>** [0:many]Points to the file location of the learning object. This field can be used to specify an alternate location for acquiring the resource other than the content package.
    - **<requirement>** [0:many]Represents a list of minimum technical requirements for running the learning object.
    - **<installationRemarks>** [0:1]Textual field for conveying specific instructions for installing this learning object.
    - **<otherPlatformRequirements>** [0:1]Textual field for listing system requirements that do not fit into the structured vocabulary of the requirement element.
    - **<duration>** [0:1]Represents the amount of time the learning object occupies when delivered at the intended speed. (Useful for assets like video files or audio clips.)
  - **<educational>** [0:1]The educational container element holds information about the educational or pedagogic characteristics of the learning object.
  - **<rights>** [0:1]The rights container element holds information about the intellectual property rights associated with this learning object.
    - **<cost>** [0:1]Yes/No element about whether or not there is a financial cost associated with using this learning object.
    - **<copyrightAndOtherRestrictions>** [0:1]Yes/No element about whether or not this learning object is copyrighted or has any other usage restrictions.
    - **<description>** [0:1]A textual description about the allowed use of the learning object.
  - **<relation>** [0:many]The relation category describes this learning object's relationship with other components.
    - **<kind>** [0:1]The type of relationship being described (ispartof, haspart, isversionof, hasversion, isformatof, hasformat, references, isreferencedby, isbasedon, isbasisfor, requires, isrequiredby).
    - **<resource>** [0:1]The component that this learning object is related to.
      - **<identifier>** [0:many]Unique identifier of the related component.
      - **<description>** [0:many]A textual description of this relationship.
  - **<annotation>** [0:many]The annotation container provides a way for authors to make additional comments on the educational use of this learning object.
  - **<classification>** [0:1]The classification container element is used to categorize this learning object within the context of a controlled vocabulary or classification system.

Figure 20–SCORM 2004 Metadata Structure [42].

To perform the integration of patterns, the implemented solution firstly proposes the correspondence between the categories of SCORM CAM metadata schema [10] and those defined by MPEG-21 metadata schema.

To match the specifications of these metadata standards the proceeding adopted in this research consists on mapping their categories using for this procedure the XPath syntax, as it was primary done mapping and matching DCMI – Dublin Core and SCORM metadata schemas, as shown in Table VIII.

This mapping is expressed in *XPath syntax*.

As we can observe in Table IV, these identifiers cover from the most generic ones to the most specifics, related to the Rights, for example, which is also a focus of ADL standardization concerning MPEG-21 and SCORM.

Matching SCORM (LOM) / DCMI	
SCORM	**DCMI**
/lom/general/identifier/entry	/dc/identifier
/lom/general/title	/dc/title
/lom/general/language	/dc/language
/lom/general/description	/dc/description
/lom/general/keyword or /lom/classification/keyword with classification/purpose equals to “Discipline” or “Idea”	/dc/subject
/lom/general/coverage	/dc/coverage
/lom/educational/learningresourcetype	/dc/type
/lom/lifecycle/contribute/date with lifecycle/contribute/role equals to “Publisher”	/dc/date
/lom/lifecycle/contribute/entity with lifecycle/contribute/role equals to “Author”	/dc/creator
/lom/lifecycle/contribute/entity with the contributing type specified in lifecycle/contribute/role	/dc/othercontributor
/lom/lifecycle/contribute/entity with lifecycle/contribute/role equals to “Publisher”	/dc/publisher
/lom/technical/format	/dc/format
/lom/rights/description	/dc/rights
/lom/relation/resource/description	/dc/relation
/lom/relation/resource with relation/kind equals to “IsBasedOn”	/dc/source

Table VIII–Mapping of SCORM and DCMI metadata (XPath syntax)

The presented mapping is a first preparatory study relating two metadata formats through the W3C XPath syntax.

From Table VIII, concerning the matching between SCORM and Dublin Core metadata standards, it is possible to analyze a projection for the expected results achieved through the work on the further mapped hybrid ontology proposed, implying in its turn SCORM and MPEG-21 metadata standards.

It can be perfectly noticed the syntax of the XPath language used for the mapping and matching system, presented in a neutral way between both metadata structures of representation.

It was found out matches among all the 15 (fifteen) elements presented in the DCMI – Dublin Core standard and in the other hand fifteen similar elements found within the SCORM metadata structure, which is actually LOM structure, as already explained in this chapter.

7. IMPLEMENTATION: MPEG-21 AND SCORM MAPPING IN XPATH LANGUAGE

The objectives of the Motion Picture Experts Group initiative on MPEG-21 [13] (ISO/IEC 21000), are: to provide a vision for a multimedia framework to enable transparent and augmented use of multimedia resources across a wide range of networks and devices to meet the needs of all users; to facilitate the integration of components and standards in order to harmonize technologies for the creation, management, manipulation, transport, distribution and consumption of content; to provide a strategy for achieving a multimedia framework by the development of specifications and standards based on well-defined functional requirement through collaboration with other bodies.

MPEG-7 and MPEG-21 have also concentrated on defining XML representations of their description schemes using the XML Schema language. Although XML Schemas provide support for explicit structural, cardinality and data typing constraints, they provide little support for the semantic knowledge necessary to enable efficient and flexible mapping, integration, and knowledge acquisition.

Central to the development of semantic analysis and knowledge mining tools for multimedia is the need for ontologies which express the key entities and relationships used to describe multimedia in a formal machine representation, *e.g,* RDF Schema or the Web Semantics Ontology Web Language (OWL). The knowledge representation provided by such ontologies can be used to develop sophisticated services and tools which perform knowledge based reasoning, knowledge adaptation, knowledge integration and sharing and knowledge acquisition, specifically for semantical lyric audiovisual content.

Consequently we have developed the following three ontologies which we will describe in detail: A resulting top-level integrated MPEG-SCORM ontology; an ontology for SCORM; an ontology for MPEG21 (includes MPEG-7).

To perform the integration of patterns, the implemented solution firstly proposes the correspondence between the categories of SCORM CAM metadata schema and those defined by MPEG-21 metadata schema.

To match the specifications of these metadata standards the proceeding adopted in this research consists on mapping their categories using for this procedure the XPath syntax,

Considering its natural structure, SCORM Content Aggregation Model (CAM) metadata schema is the related section of SCORM standard which allows delineating a new structured Ontology integrating SCORM standard and MPEG-21 metadata schema.

MAPPING DEMONSTRATION

The MPEG-21 XML schema used as the source for mapping and matching can be observed below:

Identifier Entry

```
<DIDL xmlns="urn:mpeg:mpeg21:2002:02-DIDL-NS"
   xmlns:mpeg7="urn:mpeg:mpeg7:schema:2001"
   xmlns:foo="http://www.bar.org/title-schema"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
 <Container id="C1">
```

Figure 21–Identifier Entry [12].

Identifier Catalog

```
<Container id="C1">
 <Descriptor id="D1">
   <Descriptor>
     <Statement mimeType="text/xml">
       <Relation xsi:type="mpeg7:RelationType" name="titleOf">
         <mpeg7:Argument idref="D1"/>
         <mpeg7:Argument idref="C1"/>
       </Relation>
     </Statement>
   </Descriptor>
```

Figure 22–Identifier Catalog [12].

Title

Learning object’s name in MPEG-21:

```
<Item>
 <Descriptor>
  <Statement mimeType="text/plain">
   Johnny’s first day at school
  </Statement>
 </Descriptor>
```

Figure 23–Identifier Title [12].

As well as in the format represented in the following coding, where “Title” metatag is inserted into representational “foo” namespace:

```
<Item>
 <Descriptor>
  <Statement mimeType="text/xml">
   <foo:TITLE>Photo Album #1</foo:TITLE>
  </Statement>
 </Descriptor>
```

Figure 24–Identifier Title [12].

Yet, as represented by a MPEG-7 metadata tag:

```
<Descriptor>
 <Statement mimeType="text/xml">
  <mpeg7:Mpeg7>
   <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
    <mpeg7:Creation>
     <mpeg7:Title>
      Photo Album #1
     </mpeg7:Title>
    </mpeg7:Creation>
   </mpeg7:DescriptionUnit>
  </mpeg7:Mpeg7>
 </Statement>
</Descriptor>
```

Figure 25–Identifier Title [12].

Language (MPEG-7 metatag)

```
<Descriptor id="SONG1_TITLE">
 <Statement mimeType="text/xml">
  <Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001">
   <DescriptionUnit xsi:type="CreationInformationType">
    <Creation>
     <Title xmlns:lang="en">Save It</Title>
    </Creation>
   </DescriptionUnit>
  </Mpeg7>
 </Statement>
</Descriptor>
```

Figure 26–Language [12, p.69]

Resource Identifier and Resource Format

As specified in the MPEG-21 Part 2 (ISO 21000-2) Norm, the Resource element implies two main attributes, ref (reference) for the resource identification, and mimeType attribute, which specifies the data type of the given resource.

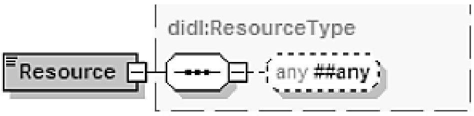
<table>
<tr><td>Diagram</td><td colspan="3">
</td></tr>
<tr><td>Used by</td><td colspan="3"><Component></td></tr>
<tr><td rowspan="3">Attributes</td><td>Name</td><td>Type</td><td>Description</td></tr>
<tr><td>mimeType</td><td>string</td><td>Specifies the data type of the resource, before any of the content-encodings specified in the CONTENTENCODING attribute were applied to the resource, as a concatenation of MIME media-type, sub-type, and parameters, as defined in IETF RFC 2045.</td></tr>
<tr><td>ref</td><td>anyURI</td><td>The URI value that identifies the resource. If the REF attribute is omitted, then the element shall contain the resource inline as character data or well-formed XML.</td></tr>
</table>

Figure 27–Resource [12, p.23]

The Norm also presents an example of XML coding where the Resource element is represented:

```
<Component>
    <Condition require="MED_QUALITY"/>
    <Descriptor>
        <xi:include xpointer="element(MED QUALITY DESC/1)"/>
    </Descriptor>
    <Descriptor>
        <xi:include xpointer="element(COMMON_PROFILE_DESC/1)"/>
    </Descriptor>
    <Resource ref="rtsp://telemedia1/v12.mp4" mimeType="video/mp4v-es"/>
</Component>
```

Figure 28–Resource [12, p.59]

RDF Namespace / LOM language categories: Coverage, Language, Keyword, Location, Learning Resource Type, Size, Duration

This excerpt shows how different descriptor formats can be used to express overlapping metadata sets. This allows a wider range of applications to access the metadata. If a particular application understands one format but not the other, it can simply ignore the other descriptor and still make full use of the Digital Item. This example shows MPEG-7 and RDF Namespace based Dublin Core descriptors.

Also note that the Component in this Digital Item has more than one Resource element, indicating multiple equivalent mechanisms for retrieving the same resource data.

```xml
        <Descriptor>
            <Statement mimeType="text/xml">
                <rdf:Description>
                    <dc:title>When the Thistle Blooms</dc:title>
                    <dc:creator>Always Red</dc:creator>
                    <dc:publisher>PDQ Records</dc:publisher>
                </rdf:Description>
            </Statement>
        </Descriptor>
        <Component>
            <Resource ref="rtsp://telemedia1:/v11.mp4" mimeType="audio/mp4a-latm"/>
            <Resource ref="urn:doi:10.1000-1" mimeType="audio/mp4a-latm"/>
        </Component>
    </Item>
</DIDL>
```

```xml
<Descriptor>
 <Statement mimeType="text/xml">
  <rdf:RDF>
   <rdf:Description>
    <dc:coverage>233</dc:coverage>
   </rdf:Description>
  </rdf:RDF>
 </Statement>
</Descriptor>
```

Figure 29–RDF [12, p.74]

Role (MPEG-7 metatag)

```xml
<Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001">
 <DescriptionUnit xsi:type="CreationInformationType">
  <Creation>
   <Title xmlns:lang="en">Always Red</Title>
   <Creator>
    <Role href="urn:mpeg:mpeg7:cs:RoleCS:2001:PERFORMER"/>
```

Figure 30–RDF [12, p.59]

Date Timepoint and Copyright String (MPEG-7 metatags)

```
        <CreationCoordinates>
         <Date>
          <TimePoint>1995-10-24</TimePoint>
         </Date>
        </CreationCoordinates>
        <CopyrightString>Copyright 1995, Acme Records, All Rights Reserved.
         Unauthorized duplication is a violation of applicable laws.
        </CopyrightString>
       </Creation>
      </DescriptionUnit>
     </Mpeg7>
    </Statement>
   </Descriptor>
```

Figure 31–Date [12, p.65]

Using the XPath language as default tool to format the taxonomies and create a new ontology, there were first mapped the following SCORM CAM metadata schema, which would correspond to the schema of MPEG-21 multimedia standard, aligned to the concept of platform's convergence. As follows in Table IX:

SCORM Multimedia Metadata	**MPEG-21 DIDL Metadata**
/lom/general/identifier/entry	<mpeg21> /container/container@id
/lom/general/identifier/catalog	<mpeg21> /container/descriptor/descriptor@id
/lom/general/description	<mpeg21> /container/descriptor/statement
/lom/general/title	<mpeg21> /item/descriptor/statement Or /item/descriptor/statement/foo:TITLE
/lom/general/language	<mpeg7> /item/descriptor/statement/mpeg7/ descriptionunit/creation/title@xmlns:lang Or <mpeg21> /item/descriptor/statement/rdf/lom:language
/lom/general/keyword	<mpeg21> /item/descriptor/statement/rdf/lom:keyword
/lom/general/coverage	<mpeg21> /item/descriptor/statement/rdf/lom:coverage
/lom/educational/ learningresourcetype	<mpeg21> /item/descriptor/statement/ rdf/lom:learningresourcetype

/lom/lifecycle/contribute/role	<mpeg7> /item/descriptor/statement/mpeg7/creation/creator/role
/lom/lifecycle/contribute/date/dateTime	<mpeg7> /item/descriptor/statement/mpeg7/creationcoordinates/date/timepoint
/lom/technical/format	<mpeg21> /item/component/resource@mimeType
/lom/technical/location	<mpeg21> /item/descriptor/statement/rdf:description /lom:location
/lom/technical/size	<mpeg21> /item/descriptor/statement/rdf:description/lom:size
/lom/technical/duration	<mpeg21> /item/descriptor/statement/rdf:description/lom:duration
/lom/relation/resource/identifier/entry	<mpeg21> item/component/resource@ref
/lom/relation/resource/description	<mpeg21> item/component/descriptor/statement
/lom/rights/description	<mpeg7> /item/descriptor/statement/mpeg7/desciptionunit/copyrightstring

Table IX–SCORM and MPEG-21 metadata standards mapped.

Table IX stands for mapping and matching between both metadata standards: SCORM and MPEG-21.

The mapped elements of both standards are up to be matched, on the purpose of achieving the hybrid ontology witch establishes the convergence between e-learning SCORM metadata standard with multimedia

MPEG-21 metadata standard, interoperable and applicable for the wide range of digital media, including the web, mobile media or even digital television.

THE IMPLEMENTED ONTOLOGY

This proposed interoperable SCORM MPEG-21 ontology, employing the W3C XPath language, focus on the main items whose approaching is mandatory for achieving a significant representation of the metadata elements necessary to both a multimedia digital item description and a learning object description as well, developing a common hybrid new ontology based on the body and syntax of the existing ones.

SCORM

The methodology for designing the SCORM Ontology was analyzing the LOM/SCORM hierarchic structure and filtering the items which are considered essentials for a rich representation of a digital media object item.

This is the SCORM Ontology resulting from the categories set as equivalent to MPEG ones, so used for the MPEG-SCORM Ontology.

General

- Identifier
  - Entry
  - Catalog
- Title
- Description
- Language
- Keyword
- Coverage

Educational

- Learning Resource Type

Life Cycle

Contribute

Date and Time

Role

Technical

Format

Location

Size

Duration

Relation

Resource

Identifier

Description

Rights

Description

MPEG-21

On the other hand, there is the MPEG-21 selected Ontology, as a by-product from the categories set as equivalent to SCORM ones, used for the MPEG-SCORM Ontology.

The methodology for the MPEG-21 Ontology was analyzing the MPEG-21 Part 3 Norm hierarchic structure, concerning the DID categorization, and matching the items detected to the similar ones detected within the previously designed SCORM metadata Ontology. Not to all of them was found equivalency in SCORM, so the final result corresponds to a match.

The single MPEG-21 Ontology is presented as follows:

DIDL

Container@id

- **Descriptor**@id
  - Statement

Item

- **Descriptor**
  - Statement
    - Title
    - RDF:Description
      - LOM:Language
      - LOM:Keyword
      - LOM:Coverage
      - LOM:Size
      - LOM:Duration
      - LOM:Location
      - LOM:Learning Resource Type
    - MPEG7
      - Creation
        - Creator
          - Role
      - Creation Coordinates
        - Date
          - Time Point
      - Description Unit
        - Copyright String
          - Creation
            - Title@xmlns:lang
- **Component**
  - Resource@mimeType
  - Resource@ref
  - **Descriptor**
    - Statement

MPEG-SCORM ONTOLOGY

Finally, it is achieved the MPEG-21/SCORM mutual Ontology, as a by-product set from the equivalent categories between both metadata structures, here representing the MPEG-SCORM Ontology.

As a hybrid ontology, it is presented in the shape of a double linked interchangeble net structure, illustrating the complexity of the generated ontology tree.

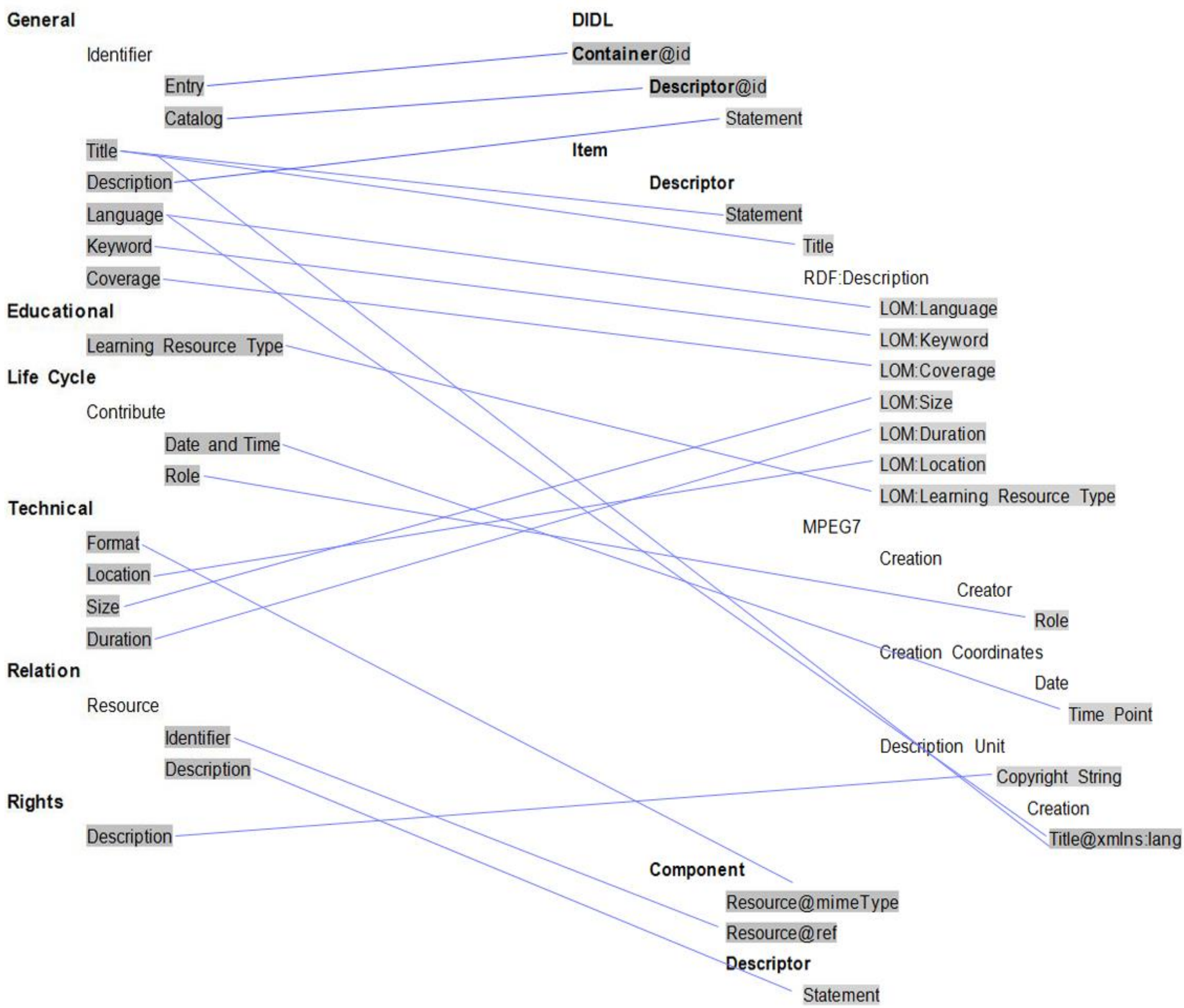


Figure 32–MPEG21-SCORM Ontology. Source: own authoring.

Ontologies can be represented or in a graphical format, as well as in table format – recovering Figure 6 (p.83):

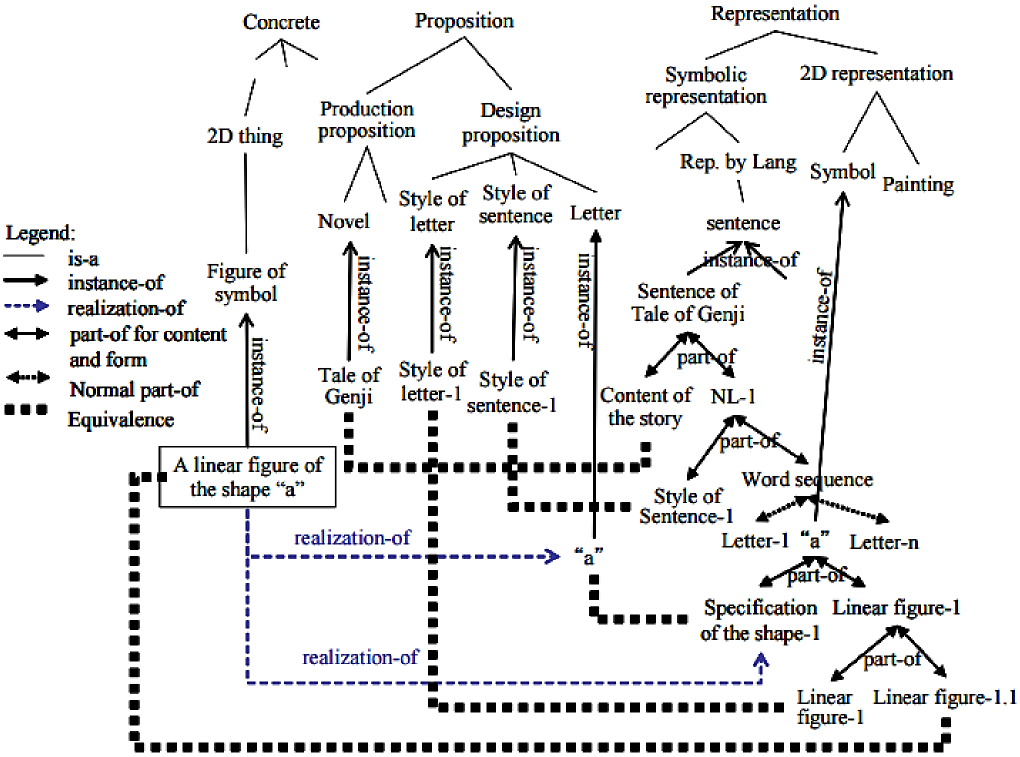


Figure 6–Example of graphical Ontology [32].

Comparing Figure 6 and Figure 32, as we can promptly observe, the kind of relation among classes in the MPEG21-SCORM Ontology created here is established entirely in the form of **is-a or inheritance** relationships, represented by a simple and direct dash linking each other or groups of them.

That relation means that one term from a paradigm is equivalente to the respective one form the other paradigm.

Beyond the ontology created from the study process on mapping and matching both metadata systems, the implementation comprehends the XML file generated through the process of codification within the metadata standard syntax.

As it was formerly seen, SCORM Manifest, or “imsmanifest.xml”, the XML file generated through the metadata categorization process, contains inside the three greater umbrella categories: metadata tag "<metadata>", the organization tag "<organizations>" and the resource tag "<resources>", followed by its sub items in indentation, exactly as the schematic representation diagram in the SCORM CAM package, as seen in Figure 17.

```
<metadata>
  <schema>ADL SCORM</schema>
  <schemaversion>2004 4th Edition</schemaversion>
</metadata>
<organizations default="ORG-4BF8CA544F0C5AB2D67407854D8EB322">
  <organization identifier="ORG-4BF8CA544F0C5AB2D67407854D8EB322" structure="hierarchical">
    <title>Ligações químicas</title>
    <item identifier="ITEM-B4654588FC70AE58CA00E26C17FC1A5E" identifierref="resource-covalent" isvisible="true">
      <title>Item</title>
    </item>
  </organization>
</organizations>
<resources>
  <resource identifier="resource-covalent" adlcp:scormType="asset" href="covalent.html" type="webcontent">
    <file href="covalent.html" />
  </resource>
```

Figure 17-SCORM Manifest [10].

One given example within the MPEG-21 ISO 21000 Part 2 norm, also formerly presented [3] in this Thesis, illustrates a media package schematic representation of a MPEG-21 music album, as it follows.

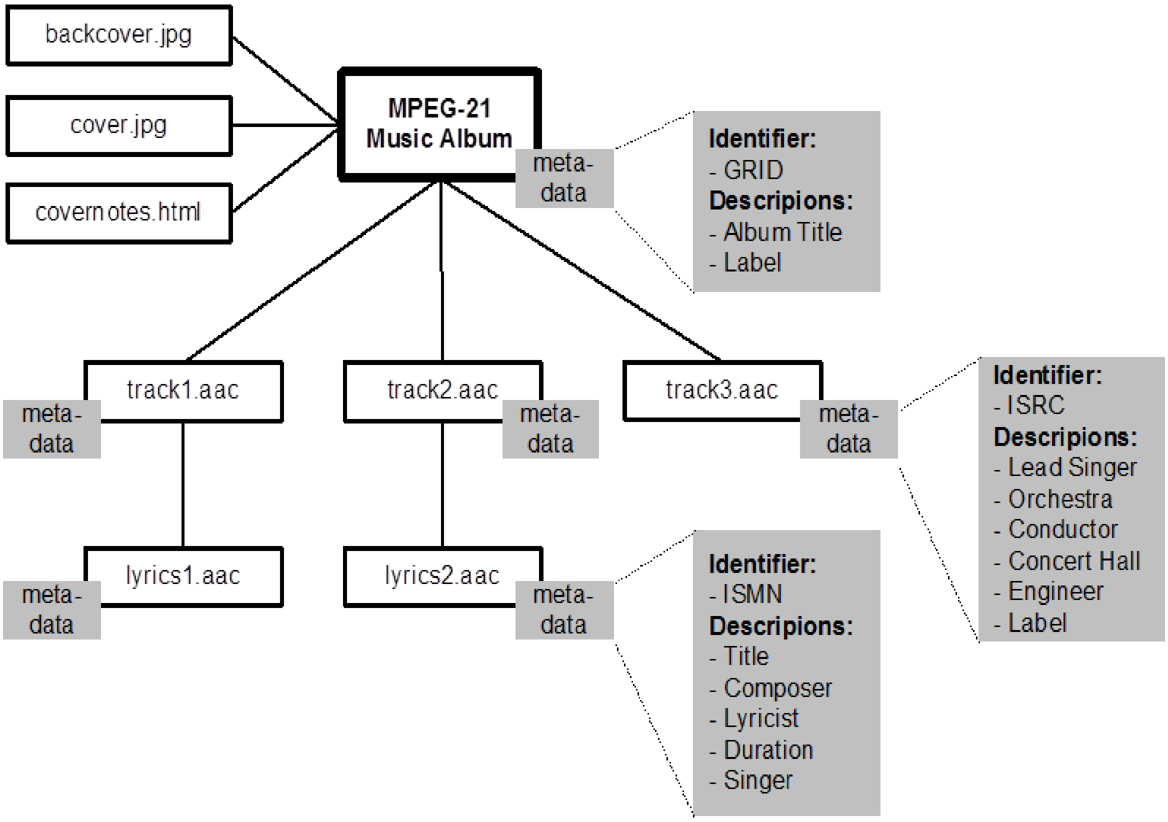


Figure 15–MPEG-21 metadata representation of a descripted media – a digital music album [12].

The XML MPEG-21 file, coded in Digital Item Declaration Language (DIDL), representing a similar album could be defined by the following coded structure, on Figure 33 and 34.

```xml
<?xml version="1.0"?>
<!-- This is a Digital Item Declaration for the (fictitious) musical album "Always Red".
-->
<DIDL xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:dc="http://purl.org/dc/elements/1.1/"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:xi="http://www.w3.org/2001/XInclude"
   xmlns:dsig="http://www.w3.org/2000/09/xmldsig#"
   xmlns="urn:mpeg:mpeg21:2002:02-DIDL-NS"
   xmlns:mx="urn:mpeg:mpeg21:2003:01-REL-MX-NS">
 <Container>
  <!-- This Container is acting as a delivery package for a particular
     consumer. The package contains information about the package, in
     this case, the recipient's name and the distributor's name. -->
  <Descriptor>
   <Statement mimeType="text/xml">
    <Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001">
     <DescriptionUnit xsi:type="CreationInformationType">
      <Creation>
       <Title xmlns:lang="en">Always Red</Title>
       <Creator>
        <Role href="urn:mpeg:mpeg7:cs:RoleCS:2001:DISTRIBUTOR"/>
        <Agent xsi:type="OrganizationType">
         <Name>Digital Music Unlimited</Name>
        </Agent>
       </Creator>
      </Creation>
     </DescriptionUnit>
    </Mpeg7>
   </Statement>
  </Descriptor>
  <Item>
   <!-- Define a set of descriptive information associated with the
     outermost item - the album as a whole. -->
   <Descriptor>
    <!-- The following statement is an example of an application-specific
       data instance that can be included, in this case, a format
       specific to the Digital Music Unlimited service. This example
       happens to be encoded in plain text, but it is possible to encode
       such data in any format compatible with well-formed XML. -->
    <Statement mimeType="application/x-dmu-content-organizer-hints">
     DMU 9876:: Item Type="Music Album";
    </Statement>
   </Descriptor>
   <Descriptor>
    <xi:include
     xpointer="xpointer(//Descriptor[@id='ALBUM_RATING']/*)element(ALBUM_RATING/2)"/>
   </Descriptor>
   <Descriptor id="PERFORMING_GROUP">
    <Statement mimeType="text/xml">
     <Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001">
      <DescriptionUnit xsi:type="CreationInformationType">
       <Creation>
        <Title xmlns:lang="en">Always Red</Title>
        <Creator>
         <Role href="urn:mpeg:mpeg7:cs:RoleCS:2001:PERFORMER">
          <Term termID="urn:mpeg:mpeg7:cs:RoleCS:2001:MUSICIAN"/>
         </Role>
         <Agent xsi:type="PersonGroupType">
          <Name>Once Blue</Name>
         </Agent>
        </Creator>
       </Creation>
      </DescriptionUnit>
     </Mpeg7>
    </Statement>
   </Descriptor>
```

Figure 33–MPEG-21 DIDL Digital album [12, Edited from p.60-78]

```
<!-- Each of the following items represents a single song on the album -->
<Item>
 <Condition require="SONG1"/>
 <Descriptor>
  <Statement mimeType="application/x-dmu-content-organizer-hints">
   DMU 9876:: Item Type="Song";
  </Statement>
 </Descriptor>
 <Descriptor id="SONG1 TITLE">
  <Statement mimeType="text/xml">
   <Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001">
    <DescriptionUnit xsi:type="CreationInformationType">
     <Creation>
      <Title xmlns:lang="en">Save It</Title>
     </Creation>
    </DescriptionUnit>
   </Mpeg7>
  </Statement>
 </Descriptor>
 <Descriptor>
  <Statement mimeType="text/xml">
   <rdf:RDF>
    <rdf:Description>
     <dc:coverage>233</dc:coverage>
    </rdf:Description>
   </rdf:RDF>
  </Statement>
 </Descriptor>
 <Descriptor>
  <xi:include xpointer="element(RIGHTS/1)"/>
 </Descriptor>
 <Descriptor>
  <xi:include
  xpointer="xpointer(//Descriptor[@id='ALBUM_RATING']/*)element(ALBUM_RATING/2)"/>
 </Descriptor>
 <Component>
  <Condition require="LOW BITRATE"/>
  <Resource ref="http://www.dmu.com/always_red/01_Save_It.mp3"
    mimeType="audio/mpeg"/>
  <Anchor precedence="50">
   <Descriptor>
    <Statement mimeType="text/plain">
     Play Song
    </Statement>
   </Descriptor>
  </Anchor>
 </Component>
 <Component>
  <Condition require="HIGH BITRATE"/>
  <Resource ref="http://www.dmu.com/always_red/01_Save_It_192.mp3"
    mimeType="audio/mpeg"/>
  <Anchor precedence="100">
   <Descriptor>
    <Statement mimeType="text/plain">
     Play Song
    </Statement>
   </Descriptor>
  </Anchor>
 </Component>
 <Component>
  <Condition require="GET LYRICS"/>
  <Condition require="WANT_EXTRA_CONTENT"/>
  <Resource ref="http://www.dmu.com/always red/Save It.txt"
    mimeType="text/plain"/>
  <Anchor precedence="25">
   <Descriptor>
    <Statement mimeType="text/plain">
     View Lyrics
    </Statement>
   </Descriptor>
  </Anchor>
 </Component>
</Item>
</Container>
</DIDL>
```

Figure 34–MPEG-21 DIDL Digital album [12, Edited from p.60-78]

This presented structure has got all the elements needed to be translated to the SCORM XML imsmanifest.xml file, and virtually be imported to a LMS (Learning Management System) for the intention of building an online course within a web environment.

SCORM and MPEG-21 Parallel Implementation

The implementation demonstrating the interoperable mapping between SCORM and MPEG-21 metadata will take place exemplifying a set of MPEG-4 videos composing the explanation

The application of the MPEG21 Digital Item Declaration Language to represent complex digital objects, from a functional perspective, is attractive due to the flexibility offered by its well specified data model, and because of the extensibility provided by the Descriptor approach.

The MPEG-21 metadata standard itself makes use of those Descriptors to provide a fundamental solution for the identification of entities, to associate processing methods with entities, to express rights related to entities, and to allow for the enforcement of those rights.

In this way, Descriptors have been used within XML metadata syntax to enforce an identifier centric document model, to implement a dynamic association between entities and processing methods, and to introduce a novel way to express relationships.

In a general manner, Descriptors can be used as a tool to address specific interoperability requirements. Regarding the use of DIDL for the representation of complex digital objects for the purpose of digital preservation and reusability, it has been very effective to use Descriptors as a technique to map SCORM metadata categories to the DIDL data model.

MPEG-21 XML file structure demonstrating the implementation of a set of MPEG-4 videos metadata, mapped in equivalence to SCORM imsmanifest.xml, is schematically structured as follows:

```
<DIDL xmlns="urn:mpeg:mpeg21:2002:02-DIDL-NS"
        xmlns:mpeg7="urn:mpeg:mpeg7:schema:2001"
        xmlns:foo="http://www.bar.org/title-schema"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
   <Container id="Fundamentals">
      <Descriptor id="Title">
         <Statement mimeType="text/plain">European Higher Education System</Statement>
      </Descriptor>
      <Descriptor>
         <Statement mimeType="text/xml">
            <mpeg7:Mpeg7>
               <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
                  <mpeg7:Creation>
                     <mpeg7:Title> European Higher Education System </mpeg7:Title>
                  </mpeg7:Creation>
               </mpeg7:DescriptionUnit>
            </mpeg7:Mpeg7>
         </Statement>
       </Descriptor>
   <Item>
      <Descriptor>
         <Statement mimeType="text/xml">
            <foo:TITLE>1st Cycle – License</foo:TITLE>
         </Statement>
      </Descriptor>
      <Descriptor>
         <Statement mimeType="text/xml">
            <mpeg7:Mpeg7>
               <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
                  <mpeg7:Creation>
                     <mpeg7:Title @xmnls:lang="en">1st Cycle – License</mpeg7:Title>
                  </mpeg7:Creation>
               </mpeg7:DescriptionUnit>
            </mpeg7:Mpeg7>
         </Statement>
       </Descriptor>
       <Component>
          <Resource ref="License.mp4" mimeType="video/mp4v-es"/>
       <Descriptor>
          <Statement mimeType="text/xml">Presents the item video content
          </Statement>
       </Descriptor>
       </Component>
       <Descriptor>
```

```
            <Statement mimeType="text/xml">
                <mpeg7:Mpeg7>
                    <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
                         <mpeg7:Creation>
                             <mpeg7:Creator>
                                  <mpeg7:Role href="urn:mpeg:mpeg7:cs:RoleCS:AUTHOR" />
                             </mpeg7:Creator>
                             <CreationCoordinates>
                                  <Date>
                                       <TimePoint>2017-02-24</TimePoint>
                                   </Date>
                             </CreationCoordinates>
                             <CopyrightString>Copyright 2017, FEEC UNICAMP. All Rights Reserved.
Unauthorized duplication is a violation of applicable laws.
                             </CopyrightString>
                         </mpeg7:Creation>
                     </mpeg7:DescriptionUnit>
                 </mpeg7:Mpeg7>
            </Statement>
        </Descriptor>
        <Descriptor>
            <Statement mimeType="text/xml">
                <rdf:Description>
                    <lom:language>en</lom: language>
                    <lom:keyword>LMD system</lom: keyword>
                    <lom:coverage>Worldwide and Extemporal</lom:coverage>
                    <lom:size>10MB</lom: size>
                    <lom:duration>3000</lom: duration>
                    <lom:location>This page</lom: location>
                    <lom:learningresourcetype>Instructional video</lom: learningresourcetype>
                 </rdf:Description>
            </Statement>
        </Descriptor>
    </Item>
    <Item>
        <Descriptor>
            <Statement mimeType="text/xml">
                <foo:TITLE>2nd Cycle – Master’s</foo:TITLE>
            </Statement>
        </Descriptor>
        <Descriptor>
            <Statement mimeType="text/xml">
                <mpeg7:Mpeg7>
                    <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
                        <mpeg7:Creation>
                            <mpeg7:Title @xmnls:lang="en">2nd Cycle – Master’s </mpeg7:Title>
                        </mpeg7:Creation>
                     </mpeg7:DescriptionUnit>
                 </mpeg7:Mpeg7>
             </Statement>
        </Descriptor>
        <Component>
```

```xml
            <Resource ref="Masters.mp4" mimeType="video/mp4v-es"/>
        <Descriptor>
            <Statement mimeType="text/xml">Presents the item video content
            </Statement>
        </Descriptor>
        </Component>
        <Descriptor>
             <Statement mimeType="text/xml">
                 <mpeg7:Mpeg7>
                      <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
                           <mpeg7:Creation>
                               <mpeg7:Creator>
                                   <mpeg7:Role href="urn:mpeg:mpeg7:cs:RoleCS:AUTHOR" />
                               </mpeg7:Creator>
                       <CreationCoordinates>
                            <Date>
                                 <TimePoint>2017-02-24</TimePoint>
                            </Date>
                       </CreationCoordinates>
                       <CopyrightString>Copyright 2017, FEEC UNICAMP.  All Rights Reserved.
Unauthorized duplication is a violation of applicable laws.
                       </CopyrightString>
                           </mpeg7:Creation>
                      </mpeg7:DescriptionUnit>
                  </mpeg7:Mpeg7>
              </Statement>
        </Descriptor>
        <Descriptor>
            <Statement mimeType="text/xml">
                <rdf:Description>
                    <lom:language>en</lom: language>
                    <lom:keyword>LMD system</lom: keyword>
                    <lom:coverage>Worldwide and Extemporal</lom:coverage>
                    <lom:size>10MB</lom: size>
                    <lom:duration>3000</lom: duration>
                    <lom:location>This page</lom: location>
                    <lom:learningresourcetype>Instructional video</lom: learningresourcetype>
                 </rdf:Description>
            </Statement>
        </Descriptor>
    </Item>
    <Item>
        <Descriptor>
            <Statement mimeType="text/xml">
                <foo:TITLE>2nd Cycle – Master’s</foo:TITLE>
            </Statement>
        </Descriptor>
        <Descriptor>
            <Statement mimeType="text/xml">
                <mpeg7:Mpeg7>
                    <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
                        <mpeg7:Creation>
```

```
                        <mpeg7:Title @xmnls:lang="en">3rd Cycle – Doctorate </mpeg7:Title>
                     </mpeg7:Creation>
                   </mpeg7:DescriptionUnit>
                </mpeg7:Mpeg7>
             </Statement>
         </Descriptor>
         <Component>
            <Resource ref="Doctorate.mp4" mimeType="video/mp4v-es"/>
         <Descriptor>
            <Statement mimeType="text/xml">Presents the item video content
            </Statement>
         </Descriptor>
         </Component>
         <Descriptor>
             <Statement mimeType="text/xml">
                <mpeg7:Mpeg7>
                    <mpeg7:DescriptionUnit xsi:type="mpeg7:CreationInformationType">
                        <mpeg7:Creation>
                           <mpeg7:Creator>
                              <mpeg7:Role href="urn:mpeg:mpeg7:cs:RoleCS:AUTHOR" />
                           </mpeg7:Creator>
                     <CreationCoordinates>
                         <Date>
                             <TimePoint>2017-02-24</TimePoint>
                         </Date>
                     </CreationCoordinates>
                     <CopyrightString>Copyright 2017, FEEC UNICAMP.  All Rights Reserved.
Unauthorized duplication is a violation of applicable laws.
                     </CopyrightString>
                        </mpeg7:Creation>
                    </mpeg7:DescriptionUnit>
                 </mpeg7:Mpeg7>
              </Statement>
         </Descriptor>
         <Descriptor>
            <Statement mimeType="text/xml">
               <rdf:Description>
                  <lom:language>en</lom: language>
                  <lom:keyword>LMD system</lom: keyword>
                  <lom:coverage>Worldwide and Extemporal</lom:coverage>
                  <lom:size>10MB</lom: size>
                  <lom:duration>3000</lom: duration>
                  <lom:location>This page</lom: location>
                  <lom:learningresourcetype>Instructional video</lom: learningresourcetype>
                </rdf:Description>
            </Statement>
         </Descriptor>
   </Item>
   </Container>
</DIDL>
```

The SCORM equivalent coding, the SCORM Manifest, according to MPEG21-SCORM metadata interoperable proposal, generates an imsmanifest.xml which looks exactly like this:


```xml
<?xml version="1.0" encoding="UTF-8"?>
<!--This is a Reload version 2.5.6 SCORM 2004 Content Package document-->
<!--Spawned from the Reload Content Package Generator - http://www.reload.ac.uk-->
<manifest xmlns="http://www.imsglobal.org/xsd/imscp_v1p1"
     xmlns:imsmd="http://ltsc.ieee.org/xsd/LOM"
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xmlns:adlcp="http://www.adlnet.org/xsd/adlcp_v1p3"
     xmlns:imsss="http://www.imsglobal.org/xsd/imsss"
     xmlns:adlseq="http://www.adlnet.org/xsd/adlseq_v1p3"
     xmlns:adlnav="http://www.adlnet.org/xsd/adlnav_v1p3"
     identifier="MANIFEST-2CF8A6FC210D376145CE424AE03DA7F4"
      xsi:schemaLocation="http://www.imsglobal.org/xsd/imscp_v1p1
     imscp_v1p1.xsd http://ltsc.ieee.org/xsd/LOM lom.xsd
      http://www.adlnet.org/xsd/adlcp_v1p3
     adlcp_v1p3.xsd http://www.imsglobal.org/xsd/imsss imsss_v1p0.xsd
      http://www.adlnet.org/xsd/adlseq_v1p3
     adlseq_v1p3.xsd http://www.adlnet.org/xsd/adlnav_v1p3 adlnav_v1p3.xsd">
 <metadata>
  <schema>ADL SCORM</schema>
  <schemaversion>2004 3rd Edition</schemaversion>
  <imsmd:lom>
   <imsmd:general>
    <imsmd:identifier>
     European Higher Education System
     <imsmd:catalog uniqueElementName="Basic_Info" />
     <imsmd:entry uniqueElementName="European Higher Education System" />
    </imsmd:identifier>
    <imsmd:language>en</imsmd:language>
    <imsmd:keyword>
     <imsmd:string>LMD system</imsmd:string>
    </imsmd:keyword>
    <imsmd:coverage>
     <imsmd:string>Worldwide and Extemporal</imsmd:string>
    </imsmd:coverage>
   </imsmd:general>
   <imsmd:lifeCycle>
    <imsmd:contribute>
     <imsmd:role>
      <imsmd:value uniqueElementName="AUTHOR" />
     </imsmd:role>
     <imsmd:date>
      <imsmd:dateTime>2017-02-24</imsmd:dateTime>
     </imsmd:date>
    </imsmd:contribute>
```

```
    </imsmd:lifeCycle>
    <imsmd:technical>
      <imsmd:format> video/mp4v-es</imsmd:format>
      <imsmd:size>10MB</imsmd:size>
      <imsmd:location>This page</imsmd:location>
      <imsmd:duration uniqueElementName="300" />
    </imsmd:technical>
    <imsmd:educational>
      <imsmd:learningResourceType>
        <imsmd:value uniqueElementName="Instructional Video" />
      </imsmd:learningResourceType>
    </imsmd:educational>
    <imsmd:rights>
      <imsmd:description>
        <imsmd:string>Copyright 2017, FEEC UNICAMP.  All Rights Reserved. Unauthorized
duplication is a violation of applicable laws.</imsmd:string>
      </imsmd:description>
    </imsmd:rights>
    <imsmd:relation>
      <imsmd:resource>
        <imsmd:identifier>
          <imsmd:entry>License</imsmd:entry>
        </imsmd:identifier>
        <imsmd:identifier>
          <imsmd:entry>Master's</imsmd:entry>
        </imsmd:identifier>
        <imsmd:identifier>
          <imsmd:entry>Doctorate</imsmd:entry>
        </imsmd:identifier>
        <imsmd:description>
          <imsmd:string>Presents the item video content</imsmd:string>
        </imsmd:description>
      </imsmd:resource>
    </imsmd:relation>
  </imsmd:lom>
 </metadata>
 <organizations />
 <resources />
</manifest>
```

Both parallel implementations could demonstrate the final statute of the interoperable metadata ontology proposed, interrelating MPEG-21 and SCORM metadata syntaxes.

8. APPLICATION AND RESULTS

The elaboration of a framework that makes the interface between both fields of Multimedia/TV and e-Learning, interrelating them as the basis for an interoperable integration of these major study and productions areas of industry and knowledge, which can virtually be connected in a close future – this is one of the purposes of this research.

8.1 DIGITAL TELEVISION LEARNING MANAGEMENT SYSTEM

One of the viable applications regarding the implementation of the proposed study is developing a Learning Management System application for Digital Television, where the MPEG21-SCORM Metadata Ontology could be applied as the interoperable standard connecting the Multimedia and the e-Learning domains.

This metadata technology could make feasible a learning objects repository and at the same time a learning environment settled on the MPEG-21 Digital Items metadata.

So the defined technology could make possible the Media serving of modern MOOCs and SPOC video-based massive open or small private online courses by means of Interactive Digital Television environment.

It is employed as a role model the user interface from the Moodle environment, the most used and improved in the world, and considering certain limitations of a Digital TV interface.

The reference is justified, assuming Moodle already has a broad reference of studies carried out in its development and improvement, including involving the end user, as well as a whole community of developers and users around Moodle, as an open source application.

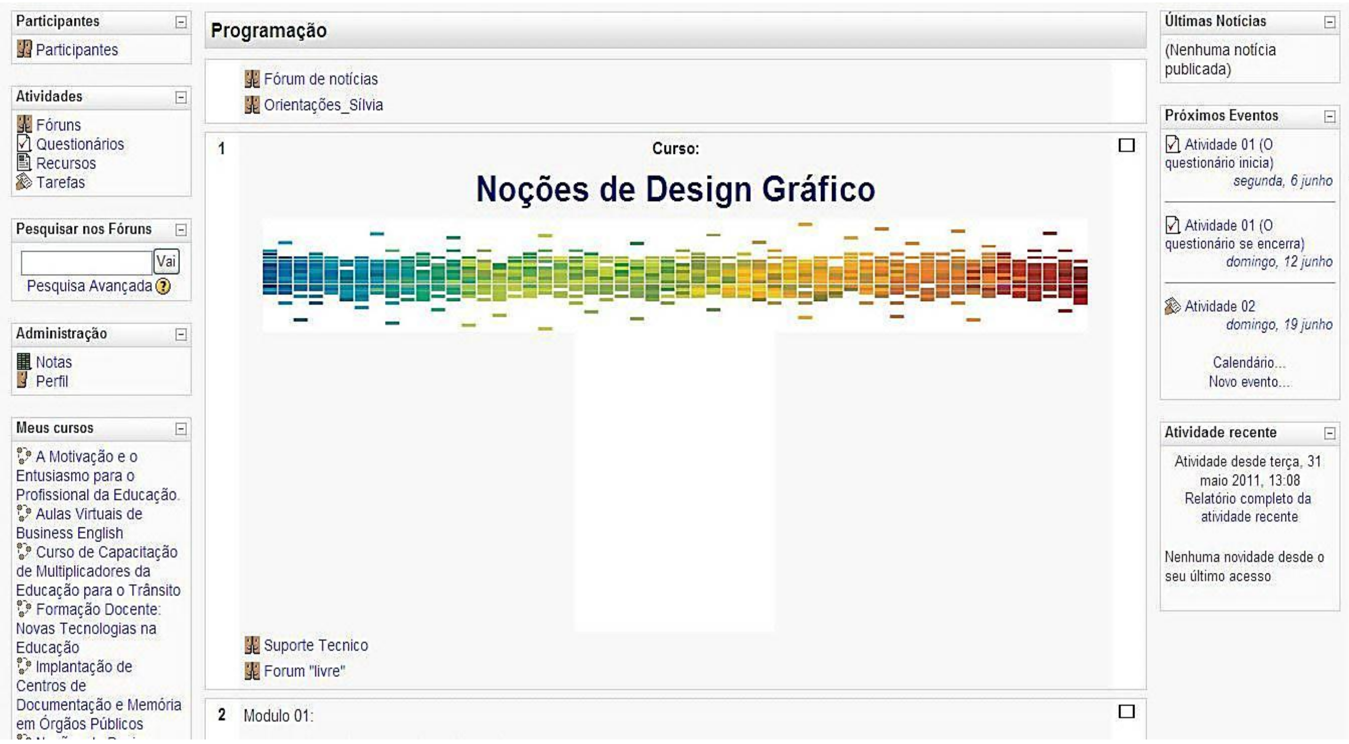


Figure 35–Moodle LMS environment user graphic interface [51].

Simulating a video class already in process, within the e-learning environment in Digital TV created, will be present in the screen HDTV format an icon of interactivity, as it is usual on the interactivities present in the current digital television broadcast.

Figure 36–Video class in full screen holding an interactivity icon [51].

Developing requirements engineering specification focusing the remote control Mapping would be mandatory for the study of the different ways of access to hypermedia pages and interface features. Noticing the functions available in the emulated control of the Ginga NCL testing software (such as the *Ginga Emulator* presented in Figure 36), in parallel with the functions of a real converter or set top box.

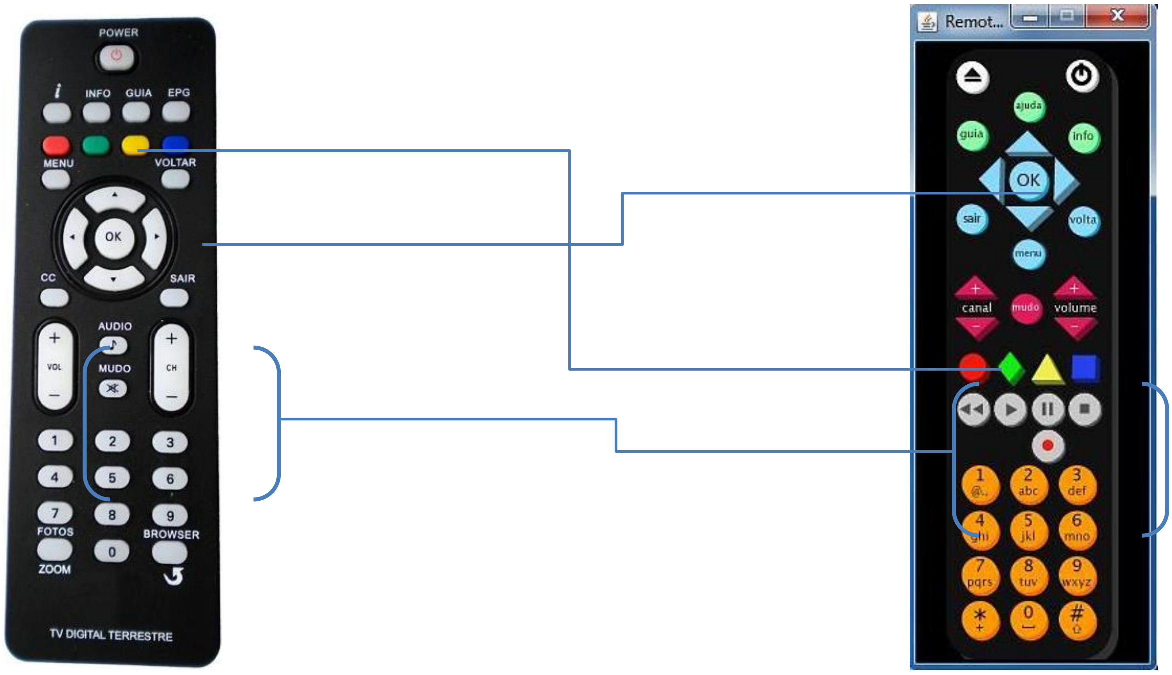


Figure 37–Usability through remote control mapping process: real interactive Digital TV control (left) in parallel with the virtual control of *Ginga Emulator* testing tool (on the right), for Ginga NCL middleware [51].

It provides a clear statement of the parallelism between its native control functions and the functionalities present at the Human-Computer interface in the proposed Distance Education application.

In this way, in Figure 38, we have the arrangement of elements in the interface when the interactivity button is activated. It was defined that the image, in a television media environment, should be kept active, displaying the video lesson or being interrupted by the "Pause" command while the user interacts with the interface functionalities.

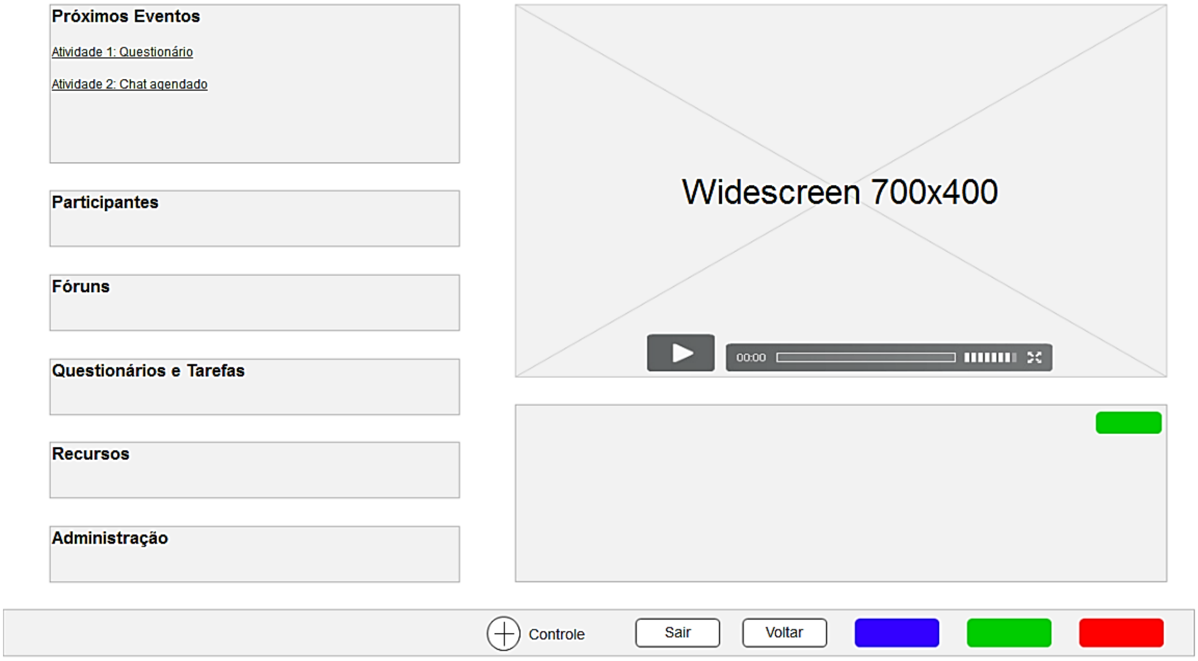


Figure 38–Access to prototype “interactivities” [51].

First of all, it can be seen that the audiovisual display screen is reduced from high definition (HD) format to a resolution of 700x400 pixels.

Adopting Moodle environment, the most used and improved in the world, as the role model to the Digital TV user interface, and considering certain limitations of a Digital TV interface, especially due to the single access peripheral considered, the remote control, the prioritization of these six essential, modular features, Initially displayed together on the screen and navigable via the directional controls on the remote, (as seen in Figure 38):

- Next Events (Próximos Eventos);
- Participants (Participantes);
- Forums (Fóruns);
- Questionnaires and Tasks (Questionários e Tarefas);

- Resources (Recursos);
- Administration (Administração).

These are the six essential features displayed on the home screen of the environment just after the access to the system is made on the server. The reference to their provision is that they are the essential functionalities also available in Moodle e-learning environment.

This constitutes a relevant purpose of the application: providing a platform of customizable resources so that the community can produce content and bring education, for example, to the Brazilian population, through Digital Television on *Ginga* Brazilian middleware, fulfilling one of the central missions to which the Brazilian System of Digital Terrestrial Television is proposed.

The MPEG21-SCORM Ontology could be used to generate interchangeable Digital Items, working as Learning Objects, so they can be used in the context of a Learning Management System for Digital Television based distance education.

8.2 DIGITAL LIBRARY REPOSITORY

Another well considered implementation regarding the application of the proposed study is applying this technology on Digital Libraries, mostly for universities.

An article [14] published by the researchers from Los Alamos National Laboratory Digital Library (LANL), maintained by the University of California, and located in New Mexico, approaches the implementation of the MPEG-21 metadata to build the repository of the LANL Digital Library. This Research Library provides extensive collections of books, journals, databases, patents and technical reports and offers literature searching, training and outreach services.

The article's abstract tells the dimension of this purpose and the importance of developing a metadata system for a Digital Library:

> Various XML based approaches aimed at representing complex digital objects have emerged over the last several years. Approaches that are of specific relevance to the Digital Library community include the Metadata Encoding and Transmission Standard (METS), the IMS Content Packaging XML Binding, the Sharable Content Object Reference Model (SCORM), and the XML packaging approach developed by CCSDS Panel 2. The MPEG21 Digital Item Declaration Language (DIDL) is another XML packaging specification that, so far, has received little attention in the Digital Library community. This article gives a brief insight into the MPEG21 standardization effort, and indicates its potential relevance to the Digital Library community. It also highlights major characteristics of DIDL, and details research conducted at the Research Library of the Los Alamos National Laboratory (LANL) into the applicability of DIDL for the representation of complex objects in the LANL repository. The positive outcome of this research has led to a decision to make DIDL conformant documents the unit of storage in the LANL repository, and suggests that DIDL could also be a valuable building block for other Digital Library projects. [14, p.1].

Contemporary Digital Libraries architectures have developed in a sense where objects that aggregate data streams of a wide variety of media types, and must allow the association of secondary data – including metadata supporting searching engines, digital preservation and rights management.

The main motivations concerning the LANL decision on adopting MPEG-21 could be summarized in the article [14] as follows:

> Potential impact of MPEG21:
>
> – MPEG [note 2] is an ISO/IEC Committee, and provides a mechanism to feed research results into an ISO standard. So far, several MPEG Standards have had a significant impact on the multimedia landscape. For example, MPEG has produced the MPEG1 and MPEG2 Standards, on which formats such as Video CD, MP3, Digital Television, and DVD are based. It is likely that the MPEG21 Standard will have a similar impact.
>
> Ability to accommodate any media type and genre:
>
> – Although MPEG21 originates in a community that focuses on motion picture, audio, and video, the MPEG21 framework can accommodate any kind of complex digital objects including electronic texts, electronic journals, scientific datasets, etc.
>
> Applicability to Digital Libraries:
>
> – There is a clear overlap between the problem domain addressed by the MPEG21 effort, and ongoing efforts regarding the representation, storage, and dissemination of complex digital objects in the Digital Library community. For example, MPEG21 DIDL and DII directly relate to the aforementioned XML-based packaging approaches [14, p.2].

Yet, the implementation of a digital library item, in MPEG-21 XML schema, was presented in an appendix within the cited article [14, p.17-20]:

LANL DID representing a technical report and metadata describing it [14, p.17-20]:

```
<?xml version="1.0" encoding="UTF-8"?>
<didl:DIDL xmlns:didl="urn:mpeg:mpeg21:2002:01-DIDL-NS">
  <didl:Container> {1}
    <!-- DID-identifier -->
    <didl:Descriptor> {5}
      <didl:Statement mimeType="text/xml; charset=UTF-8">
        <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
          urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b</dii:Identifier>
      </didl:Statement>
    </didl:Descriptor>
    <!-- PlaceHolder of Container -->
    <didl:Descriptor> {5}
      <didl:Statement mimeType="text/xml; charset=UTF-8">
        <diph:PlaceHolder
          xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
          urn:foo:TechReport</diph:PlaceHolder>
      </didl:Statement>
    </didl:Descriptor>
    <!-- Creation-datetime of Container -->
    <didl:Descriptor> {5}
      <didl:Statement mimeType="text/xml; charset=UTF-8">
        <didt:Created
          xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
          2003-09-05T21:51:01Z</didt:Created>
      </didl:Statement>
    </didl:Descriptor>
    <!-- Item accommodating descriptive metadata about technical report -->
    <didl:Item> {2}
      <!-- Content-identifier of descriptive metadata -->
      <didl:Descriptor> {5}
        <didl:Statement mimeType="text/xml; charset=UTF-8">
          <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
            urn:bar:56-8730</dii:Identifier>
        </didl:Statement>
      </didl:Descriptor>
      <!-- PlaceHolder of Item -->
      <didl:Descriptor> {5}
        <!-- PlaceHolder of Item -->
        <didl:Statement mimeType="text/xml; charset=UTF-8">
          <diph:PlaceHolder
            xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
            urn:foo:Metadata</diph:PlaceHolder>
        </didl:Statement>
      </didl:Descriptor>
      <!-- Creation-datetime of Item -->
      <didl:Descriptor> {5}
        <didl:Statement mimeType="text/xml; charset=UTF-8">
          <didt:Created
            xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
            2003-09-05T18:30:07Z</didt:Created>
        </didl:Statement>
      </didl:Descriptor>
      <!-- Relationships on an Item level -->
      <didl:Descriptor>
```

```
<didl:Statement mimeType="text/xml; charset=UTF-8">
  <dir:Relations
    xmlns:dir="http://library.lanl.gov/2003-11/MPEG-21/DIR">
    <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xml:base="urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b">
    <rdf:Description rdf:about="#//didl:Item[1]">
      <a:isPartOf xmlns:a="http://purl.org/dc/terms/#">
        <rdf:Description
        rdf:about="info:sid/library.lanl.gov:lanl-opac">
          <b:hasType xmlns:b="http://…/Relations#"
          rdf:resource="http://…/Relations#Collection"/>
        </rdf:Description>
      </a:isPartOf>
    <rdf:Description>
    <rdf:Description rdf:about="#//didl:Item[1]">
      <b:isDescriptiveMetadataOf xmlns:b="http://…/Relations#"
      rdf:resource="#//didl:Item[2]"/>
    </rdf:Description>
    </rdf:RDF>
  <dir:Relations>
</didl:Statement>
</didl:Descriptor>
<didl:Component> {3}
  <!-- PlaceHolder of datastream -->
  <didl:Descriptor> {5}
    <didl:Statement mimeType="text/xml; charset=UTF-8">
      <diph:PlaceHolder
        xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
        urn:foo:Metadata:MARC/XML</diph:PlaceHolder>
    </didl:Statement>
  </didl:Descriptor>
  <!-Creation-datetime of datastream -->
  <didl:Descriptor> {5}
    <didl:Statement mimeType="text/xml; charset=UTF-8">
      <didt:Created
        xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
        2002-05-03T14:30:03Z</didt:Created>
    </didl:Statement>
  </didl:Descriptor>
  <didl:Resource mimeType="text/xml; charset=UTF-8"> {4}
      <record xmlns="http://www.loc.gov/MARC21/slim">
      <leader>01142cam 2200301 a 4500</leader>
        <controlfield tag="005">19930521155141.9</controlfield>
        <datafield tag="010" ind1=" " ind2=" ">
          <subfield code="a">92005291</subfield>
      </datafield>
      …
  </didl:Resource>
</didl:Component>
<didl:Component> {3}
  <!-- PlaceHolder of datastream -->
  <didl:Descriptor> {5}
    <didl:Statement mimeType="text/xml; charset=UTF-8">
      <diph:PlaceHolder
        xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
        urn:foo:Metadata:MARC/RAW</diph:PlaceHolder>
    </didl:Statement>
  </didl:Descriptor>
  <!-- Creation-datetime of datastream -->
```

```
      <didl:Descriptor> {5}
        <didl:Statement mimeType="text/xml; charset=UTF-8">
          <didt:Created
            xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
            2001-02-12T11:34:02Z</didt:Created>
        </didl:Statement>
      </didl:Descriptor>
      <didl:Resource encoding="base64" mimeType="application/marc"> {4}
          j0iMS4wIiBlbmNvZGluZz0iVVRGLTgiPz4NCjxjb2xsZWN0aW9uIHhtbG5zSJodH
          RwOi8vd3d3LmxvYy5nb3YvTUFSQzIxL3NsaW0iPg0KICA8cmVjb3JkPg0KICAgID
          PD94bWWgdmVyc2lvb…
      </didl:Resource>
    </didl:Component>
  </didl:Item>
  <!-- Item accommodating technical report -->
  <didl:Item> {2}
    <!-- Content-identifier of technical report -->
    <didl:Descriptor> {5}
      <didl:Statement mimeType="text/xml; charset=UTF-8">
        <dii:Identifier xmlns:dii="urn:mpeg:mpeg21:2002:01-DII-NS">
          urn:bar:99-6537</dii:Identifier>
      </didl:Statement>
    </didl:Descriptor>
    <!-- PlaceHolder of Item -->
    <didl:Descriptor> {5}
      <didl:Statement mimeType="text/xml; charset=UTF-8">
        <diph:PlaceHolder
          xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
          urn:foo:FullReport</diph:PlaceHolder>
      </didl:Statement>
    </didl:Descriptor>
    <!-Creation-datetime of Item -->
    <didl:Descriptor> {5}
      <didl:Statement mimeType="text/xml; charset=UTF-8">
        <didt:Created
          xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
          2003-09-05T18:30:07Z</didt:Created>
      </didl:Statement>
    </didl:Descriptor>
    <!-- Relationships of Item -->
    <didl:Descriptor>
      <didl:Statement mimeType="text/xml; charset=UTF-8">
        <dir:Relations
          xmlns:dir="http://library.lanl.gov/2003-11/MPEG-21/DIR">
          <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
          xml:base="urn:uuid:10ba6842-ec45-3b19-8kub-hy8ff58c58a8b">
          <rdf:Description rdf:about="#//didl:Item[2]">
            <a:isPartOf xmlns:a="http://purl.org/dc/terms/#">
              <rdf:Description
              rdf:about="info:sid/library.lanl.gov:lanl-tr">
                <b:hasType xmlns:b="http://…/Relations#"
                rdf:resource="http://…/Relations#Collection"/>
              </rdf:Description>
            </a:isPartOf>
          <rdf:Description>
          <rdf:Description rdf:about="//didl:Item[2]">
            <b:hasDescriptiveMetadata xmlns:b="http://…/Relations#"
            rdf:resource="#//didl:Item[1]"/>
          </rdf:Description>
```

```
                </rdf:RDF>
            <dir:Relations>
        </didl:Statement>
    </didl:Descriptor>
    <didl:Component> {3}
        <!-- PlaceHolder of datastream -->
        <didl:Descriptor>
            <didl:Statement mimeType="text/xml; charset=UTF-8">
                <diph:PlaceHolder
                    xmlns:diph="http://library.lanl.gov/2003-09/MPEG-21/DIPH">
                    urn:foo:FullReport/PDF</diph:PlaceHolder>
            </didl:Statement>
        </didl:Descriptor>
        <!-Creation-datetime of datastream -->
        <didl:Descriptor> {5}
            <didl:Statement mimeType="text/xml; charset=UTF-8">
                <didt:Created
                    xmlns:didt="http://library.lanl.gov/2003-09/MPEG-21/DIDT">
                    2000-03-11T18:22:33Z</didt:Created>
            </didl:Statement>
        </didl:Descriptor> {5}
        <didl:Resource encoding="base64" mimeType="application/pdf"> {4}
            PSJjIj5jMTk5My48L3N1YmZpZWxkPg0KICAgIDw9uIHhtbG5zSJodHgKICAgIDxk
            dGFnPSIzMDAiIGluZDE9IiAiIGluZDI9IiAiPg0KICAgICAgPHN1YmZpZWxkIGNv
            cmVzdG9yZWQgdG8g…
        </didl:Resource> {4}
        <didl:Resource mimeType="application/pdf"
            ref="http://foo/bar/733902fg992.pdf"/>
    </didl:Component>
  </didl:Item>
 </didl:Container>
</didl:DIDL>
```

9. CONCLUSIONS

It was possible to obtain successful results concerning the stages overcame on this research, regarding to the implementation of the specific goal of correspondence between metadata standards of the knowledge domains issued.

The development work has consisted in creating an Ontology focused on these mapped taxonomies in order to propose, from this ontology, an integration between the fields of Multimedia (comprehending Digital Television) and MPEG ICTE for distance education / e -Learning.

In other words, the convergence between MPEG-21 and SCORM as a standard for describing objects used for cataloging and for use in e-learning, in a broader sense, and e-learning via Digital Television in a specific perspective of the field of research.

A SCORM MPEG-21 Ontology, employing the W3C XPath language, is already in an advanced stage in order to make its contribution to the body of knowledge and the process of standardization in the metadata study domain, as well to further the research there have been in development the run-time and sequencing sections within this ontology.

It also contributes to a latent need for integration between the universes of Multimedia and ICTE, represented by the working groups SC29 and SC36 standardization subcommittees, within the ISO / IEC JTC1, on this contemporary context of post-modern digital convergence.

FUTURE RESEARCH

As it could be seen from the Master's Degree research through the Doctoral investigation, the current research closes a cycle within the intersection between Multimedia and E-Learning fields of study.

Planning the future investigation there can be glimpsed an evolution towards the next step performing a Post-Doctoral research in this field of knowledge.

The next frontier of the State of the Art would convey Searching Content Data Science, Machine Learning, and even Artificial Intelligence to perform data mining for consulting, gathering and presenting data to the user of an intelligent assistant application.

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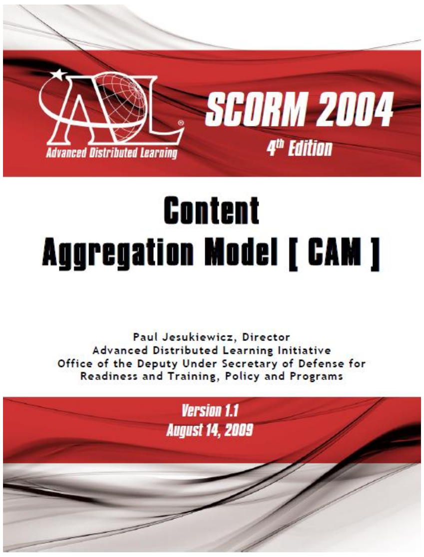
ANNEXURE

ANNEX A

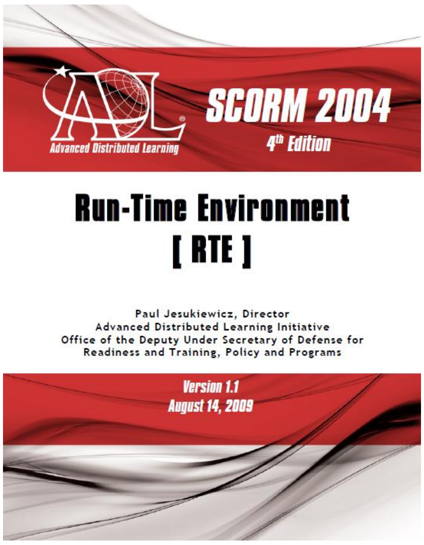
Sharable Content Object Reference Model (SCORM) documentation, v.1.1, 4th edition, 2004

SCORM Content Aggregation Model (CAM) consulting link:



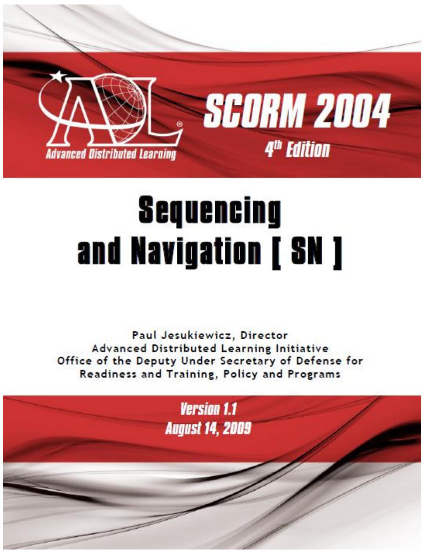
Available at <http://www.adlnet.gov/wp-content/uploads/2013/09/scorm_2004_4ed_v1_1_cam_20090814.pdf>.

SCORM Run-Time Environment (RTE) link for consulting:



Available at <http://www.adlnet.org/wp-content/uploads/2013/09/scorm_2004_4ed_v1_1_rte_20090814.pdf>.

SCORM Sequencing and Navigation (SN) link for consulting:



Available at <http://www.adlnet.org/wp-content/uploads/2013/09/scorm_2004_4ed_v1_1_sn_20090814.pdf>.

ANNEX B

Norm ISO/IEC 21000 – MPEG-21 Overview v.5

INTERNATIONAL ORGANISATION FOR STANDARDISATION

ORGANISATION INTERNATIONALE DE NORMALISATION

ISO/IEC JTC1/SC29/WG11

CODING OF MOVING PICTURES AND AUDIO

ISO/IEC JTC1/SC29/WG11/N5231

Shanghai, October 2002

Title: MPEG-21 Overview v.5

Source: Requirements Group

Editors: Jan Bormans, Keith Hill

Status: Approved

Introduction

The appetite for consuming content and the accessibility of information continues to increase at a rapid pace. Access devices, with a large set of differing terminal and network capabilities, continue to evolve, having a growing impact on peoples' lives. Additionally, these access devices possess the functionality to be used in different locations and environments: anywhere and at anytime. Their users, however, are currently not given tools to deal efficiently with all the intricacies of this new multimedia usage context.

Solutions with advanced multimedia functionality are becoming increasingly important as individuals are producing more and more digital media, not only for professional use but also for their personal use. All these "content providers" have many of the same concerns: management of content, re-purposing content based on consumer and device capabilities, protection of rights, protection from unauthorised access/modification, protection of privacy of providers and consumers, etc.

Such developments are pushing the boundaries of existing business models for trading physical goods and require new models for distributing and trading digital content electronically. For example, it is becoming increasingly difficult for legitimate users of content to identify and interpret the different intellectual property rights that are associated with the elements of multimedia content. Additionally, there are some users who freely exchange content with disregard for the rights associated with content and rights holders are powerless to prevent them. The boundaries between the delivery of audio (music and spoken word), accompanying artwork (graphics), text (lyrics), video (visual) and synthetic spaces are becoming increasingly blurred. New solutions are required for the access, delivery, management and protection processes of these different content types in an integrated and harmonized way, to be implemented in a manner that is entirely transparent to the many different users of multimedia services.

The need for technological solutions to these challenges is motivating the MPEG-21 Multimedia Framework initiative that aims to enable the transparent and augmented use of multimedia resources across a wide range of networks and devices..

For a detailed examination and description of the requirements for the MPEG-21 multimedia framework readers are advised to refer to the MPEG-21 Technical Report, “Vision, Technologies and Strategy”[17].

MPEG-21 Multimedia Framework

Based on the above observations, MPEG-21 aims at defining a normative open framework for multimedia delivery and consumption for use by all the players in the delivery and consumption chain. This open framework will provide content creators, producers, distributors and service providers with equal opportunities in the MPEG-21 enabled open market. This will also be to the benefit of the content consumer providing them access to a large variety of content in an interoperable manner

MPEG-21 is based on two essential concepts: the definition of a fundamental unit of distribution and transaction (the Digital Item) and the concept of Users interacting with Digital Items. The Digital Items can be considered the “what” of the Multimedia Framework (e.g., a video collection, a music album) and the Users can be considered the “who” of the Multimedia Framework.

The goal of MPEG-21 can thus be rephrased to: defining the technology needed to support Users to exchange, access, consume, trade and otherwise manipulate Digital Items in an efficient, transparent and interoperable way.

During the MPEG-21 standardization process, Calls for Proposals based upon requirements have been and continue to be issued by MPEG. Eventually the responses to the calls result in different parts of the MPEG-21 standard (i.e. ISO/IEC

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[17] *ISO/IEC TR 21000-1:2001(E) Part 1: Vision, Technologies and Strategy, freely downloadable from http://www.iso.ch/iso/en/ittf/PubliclyAvailableStandards*

21000-N) after intensive discussion, consultation and harmonization efforts between MPEG experts, representatives of industry and other standards bodies.

MPEG-21 identifies and defines the mechanisms and elements needed to support the multimedia delivery chain as described above as well as the relationships between and the operations supported by them. Within the parts of MPEG-21, these elements are elaborated by defining the syntax and semantics of their characteristics, such as interfaces to the elements.

User Model

The Technical Report sets out the User requirements in the multimedia framework. A User is any entity that interacts in the MPEG-21 environment or makes use of a Digital Item. Such Users include individuals, consumers, communities, organisations, corporations, consortia, governments and other standards bodies and initiatives around the world. Users are identified specifically by their relationship to another User for a certain interaction. From a purely technical perspective, MPEG-21 makes no distinction between a “content provider” and a “consumer”—both are Users. A single entity may use content in many ways (publish, deliver, consume, etc.), and so all parties interacting within MPEG-21 are categorised as Users equally. However, a User may assume specific or even unique rights and responsibilities according to their interaction with other Users within MPEG-21.

At its most basic level, MPEG-21 provides a framework in which one User interacts with another User and the object of that interaction is a Digital Item commonly called content. *Some* such interactions are creating content, providing content, archiving content, rating content, enhancing and delivering content, aggregating content, delivering content, syndicating content, retail selling of content, consuming content, subscribing to content, regulating content, facilitating transactions that occur from any of the above, and regulating transactions that occur from any of the above. Any of these are “uses” of MPEG-21, and the parties involved are Users.

Overview of Digital Items

Within any system (such as MPEG-21) that proposes to facilitate a wide range of actions involving “Digital Items”, there is a need for a very precise description for defining exactly what constitutes such an “item”. Clearly there are many kinds of content, and probably just as many possible ways of describing it to reflect its context of use. This presents a strong challenge to lay out a powerful and flexible model for Digital Items which can accommodate the myriad forms that content can take (and the new forms it will assume in the future). Such a model is only truly useful if it yields a format that can be used to represent any Digital Items defined within the model unambiguously and communicate them, and information about them, successfully. The Digital Item Declaration specification (part 2 of ISO/IEC 21000) provides such flexibility for representing Digital Items.

An Example:

Consider a simple “web page” as a Digital Item. A web page typically consists of an HTML document with embedded “links” to (or dependencies on) various image files (e.g., JPEGs and GIFs), and possibly some layout information (e.g., Style Sheets). In this simple case, it is a straightforward exercise to inspect the HTML document and deduce that this Digital Item consists of the HTML document itself, plus all of the other resources upon which it depends.

Now let’s modify the example to assume that the “web page” contains some custom scripted logic (e.g., JavaScript, etc.) to determine the preferred language of the viewer (among some predefined set of choices) and to either build/display the page in that language, or to revert to a default choice if the preferred translation is not available.

The key point in this modified example is that the presence of the language logic clouds the question of exactly what constitutes this Digital Item now and how this can be unambiguously determined.

The first problem is one of actually determining all of the dependencies. The addition of the scripting code changes the declarative “links” of the simple web page into links that can be (in the general case) determined only by running the embedded script on a specific platform. This could still work as a method of deducing the structure of the Digital Item, *assuming* that the author intended each translated “version” of the web page to be a separate and distinct Digital Item.

This assumption highlights the second problem: it is ambiguous whether the author actually intends for each translation of the page to be a standalone Digital Item, or whether the intention is for the Digital Item to consist of the page with the language choice left unresolved. If the latter is the case, it makes it impossible to deduce the *exact* set of resources that this Digital Item consists of which leads back to the first problem.

The problem stated above is addressed by the Digital Item Declaration. A Digital Item Declaration (DID) is a document that specifies the makeup, structure and organisation of a Digital Item. Part 2 of MPEG-21 contains the DID Specification.

MPEG-21 Current Work Plan

MPEG-21 has established a work plan for future standardisation. Nine parts of standardisation within the Multimedia Framework have already started (note that the Technical Report is part 1 of the MPEG-21 Standard). These are elaborated in the subsections below.

In addition to these specifications, MPEG maintains a document containing the consolidated requirements for MPEG-21[18]. This document will continue to evolve during the development of the various parts of MPEG-21 to reflect new requirements and changes to existing requirements.

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[18] The current version of the MPEG-21 Requirements document can be found at http://mpeg.telecomitalialab.com/working_documents.htm

ISO/IEC TR 21000-1: MPEG-21 Multimedia Framework Part 1: Vision, Technologies and Strategy

A Technical Report has been written to describe the multimedia framework and its architectural elements together with the functional requirements for their specification that was formally approved in September 2001.

The title "Vision, Technologies and Strategy" has been chosen to reflect the fundamental purpose of the Technical Report. This is to:

- Define a 'vision' for a multimedia framework to enable transparent and augmented use of multimedia resources across a wide range of networks and devices to meet the needs of all users

- Achieve the integration of components and standards to facilitate harmonisation of 'technologies' for the creation, management, transport, manipulation, distribution, and consumption of digital items.

- Define a 'strategy' for achieving a multimedia framework by the development of specifications and standards based on well-defined functional requirements through collaboration with other bodies.

MPEG-21 Part 2 – Digital Item Declaration

The purpose of the Digital Item Declaration (DID) specification is to describe a set of abstract terms and concepts to form a useful model for defining Digital Items. Within this model, a Digital Item is the digital representation of "a work", and as such, it is the thing that is acted upon (managed, described, exchanged, collected, etc.) within the model. The goal of this model is to be as flexible and general as possible, while providing for the "hooks" that enable higher level functionality. This, in turn, will allow the model to serve as a key foundation in the building of higher level models in other

MPEG-21 elements (such as Identification & Description or IPMP). This model specifically does not define a language in and of itself. Instead, the model helps to provide a common set of abstract concepts and terms that can be used to define such a scheme, or to perform mappings between existing schemes capable of Digital Item Declaration, for comparison purposes.

The DID technology is described in three normative sections:

- Model: The Digital Item Declaration Model describes a set of abstract terms and concepts to form a useful model for defining Digital Items. Within this model, a Digital Item is the digital representation of "a work", and as such, it is the thing that is acted upon (managed, described, exchanged, collected, etc.) within the model.

- Representation: Normative description of the syntax and semantics of each of the Digital Item Declaration elements, as represented in XML. This section also contains some non-normative examples for illustrative purposes.

- Schema: Normative XML schema comprising the entire grammar of the Digital Item Declaration representation in XML.

The following sections describe the semantic "meaning" of the principle elements of the Digital Item Declaration Model. Please note that in the descriptions below, the defined elements in *italics* are intended to be unambiguous terms within this model.

1) Container

A *container* is a structure that allows *items* and/or *containers* to be grouped. These groupings of *items* and/or *containers* can be used to form logical *packages* (for transport or exchange) or logical *shelves* (for organization). *Descriptors* allow for the "labeling" of *containers* with information that is appropriate for the purpose of the grouping (e.g. delivery instructions for a *package*, or category information for a *shelf*).

It should be noted that a *container* itself is not an *item*; *containers* are groupings of *items* and/or *containers*.

2) Item

An *item* is a grouping of sub-*items* and/or *components* that are bound to relevant *descriptors*. *Descriptors* contain information about the *item*, as a representation of a work. *Items* may contain *choices*, which allow them to be customized or conFigure d. *Items* may be conditional (on *predicates* asserted by *selections* defined in the *choices*). An *item* that contains no sub-items can be considered an entity -- a logically indivisible work. An *item* that does contain sub-*items* can be considered a compilation -- a work composed of potentially independent sub-parts. *Items* may also contain *annotations* to their sub-parts.

The relationship between *items* and Digital Items (as defined in ISO/IEC 21000-1:2001, MPEG-21 Vision, Technologies and Strategy) could be stated as follows: *items* are declarative representations of Digital Items.

3) Component

A *component* is the binding of a *resource* to all of its relevant *descriptors*. These *descriptors* are information related to all or part of the specific *resource* instance. Such *descriptors* will typically contain control or structural information about the *resource* (such as bit rate, character set, start points or encryption information) but not information describing the “content” within.

It should be noted that a *component* itself is not an *item*; *components* are building blocks of *items*.

4) Anchor

An *anchor* binds *descriptors* to a *fragment,* which corresponds to a specific location or range within a *resource*.

5) Descriptor

A *descriptor* associates information with the enclosing element. This information may be a *component* (such as a thumbnail of an image, or a text *component*), or a textual *statement.*

6) Condition

A *condition* describes the enclosing element as being optional, and links it to the *selection*(s) that affect its inclusion. Multiple *predicates* within a *condition* are combined as a conjunction (an AND relationship). Any *predicate* can be negated within a *condition*. Multiple *conditions* associated with a given element are combined as a disjunction (an OR relationship) when determining whether to include the element.

7) Choice

A *choice* describes a set of related *selections* that can affect the configuration of an *item*. The *selections* within a *choice* are either exclusive (choose exactly one) or inclusive (choose any number, including all or none).

8) Selection

A *selection* describes a specific decision that will affect one or more *conditions* somewhere within an *item*. If the *selection* is chosen, its predicate becomes true; if it is not chosen, its *predicate* becomes false; if it is left unresolved, its *predicate* is undecided.

9) Annotation

An *annotation* describes a set of information about another identified element of the model without altering or adding to that element. The information can take the form of *assertions*, *descriptors*, and *anchors*.

10) Assertion

An *assertion* defines a full or partially conFigure d state of a *choice* by asserting true, false or undecided values for some number of *predicates* associated with the *selections* for that *choice*.

11) Resource

A *resource* is an individually identifiable asset such as a video or audio clip, an image, or a textual asset. A *resource* may also potentially be a physical object. All *resources* must be locatable via an unambiguous address.

12) Fragment

A *fragment* unambiguously designates a specific point or range within a *resource*. *Fragment* may be *resource* type specific.

13) Statement

A *statement* is a literal textual value that contains information, but not an asset. Examples of likely *statements* include descriptive, control, revision tracking or identifying information.

14) Predicate

A *predicate* is an unambiguously identifiable Declaration that can be true, false or undecided.

Figure 1 is an example showing the most important elements within this model, how they are related, and as such, the hierarchical structure of the Digital Item Declaration Model.

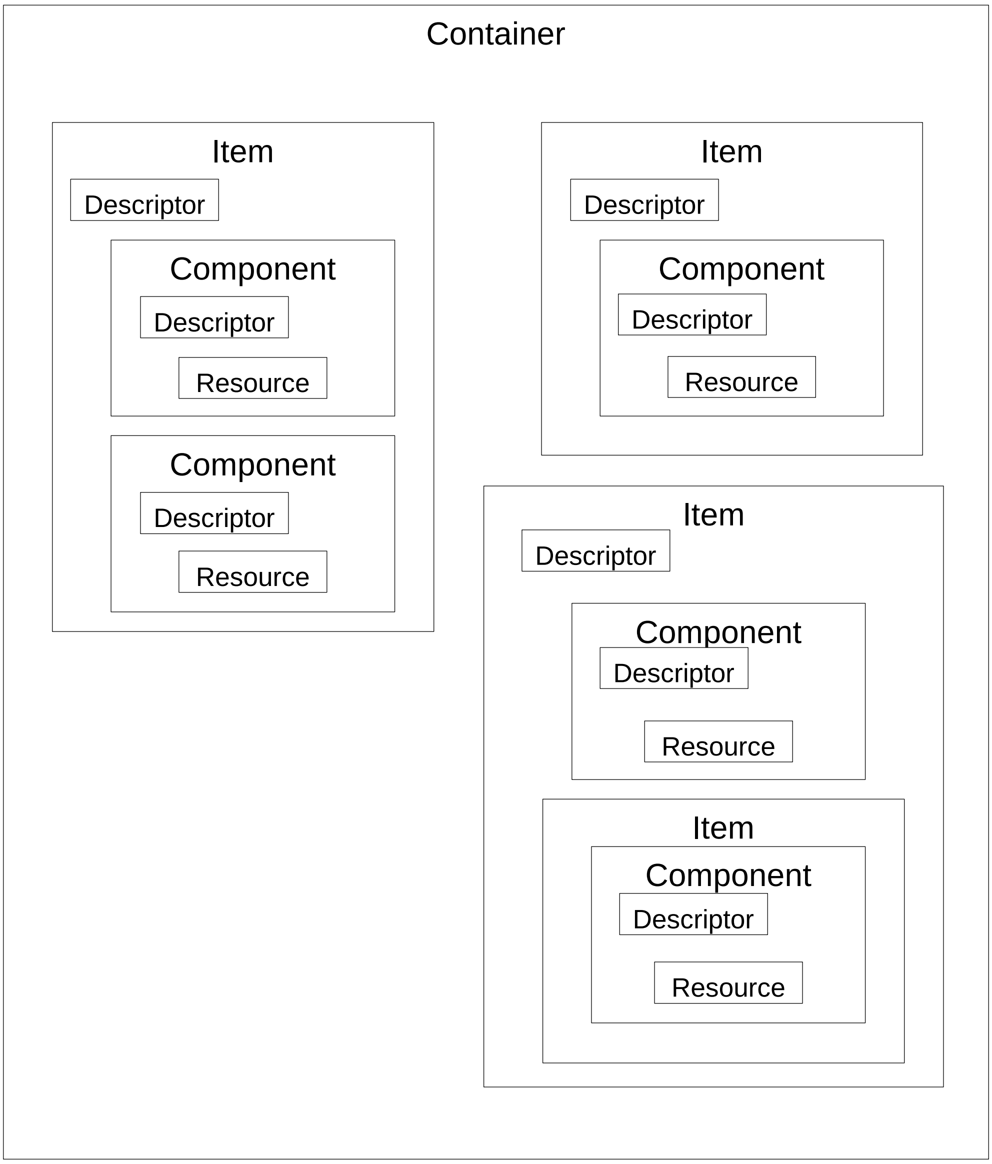

Figure 1 - Relationship of the principle elements within the Digital Identification Declaration Model

MPEG-21 Part 3 - Digital Item Identification

The scope of the Digital Item Identification (DII) specification includes:

- How to uniquely identify Digital Items and parts thereof (including resources);
- How to uniquely identify IP related to the Digital Items (and parts thereof), for example abstractions;
- How to uniquely identify Description Schemes;
- How to use identifiers to link Digital Items with related information such as descriptive metadata.
- How to identify different types if Digital Items.

The DII specification does not specifynew identification systems for the content elements for which identification and description schemes already exist and are in use (e.g., ISO/IEC 21000-3 does not attempt to replace the ISRC (as defined in ISO 3901) for sound recordings but allows ISRCs to be used within MPEG-21).

Identifiers covered by this specification can be associated with Digital Items by including them in a specific place in the Digital Item Declaration. This place is the STATEMENT element. Examples of likely STATEMENTS include descriptive, control, revision tracking and/or identifying information below shows this relationship. The shaded boxes are subject of the DII specification while the bold boxes are defined in the DID specification:

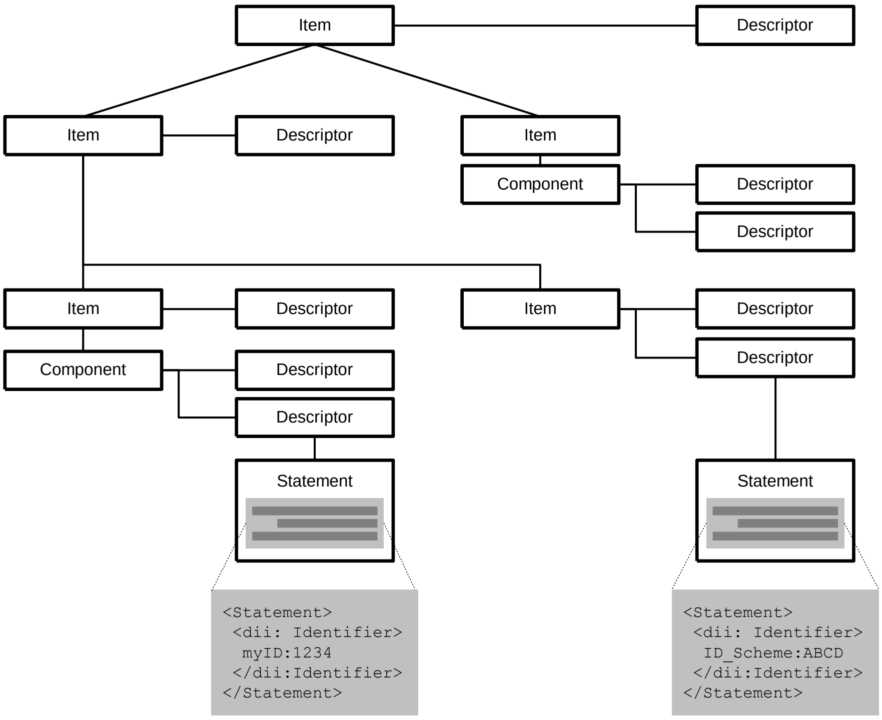

Figure 2 – Relationship between Digital Item Declaration and Digital Item Identification

Several elements within a Digital Item Declaration can have zero, one or more DESCRIPTORS (as specified in part 2). Each DESCRIPTOR may contain one STATEMENT which can contain one identifier relating to the parent element of the STATEMENT. In above, the two statements shown are used to identify a Component (left hand side of the diagram) and an Item (right hand side of the diagram).

Digital Items and their parts within the MPEG-21 Framework are identified by encapsulating Uniform Resource Identifiers into the Identification DS. A Uniform Resource Identifier (URI) is a compact string of characters for identifying an abstract or physical resource, where a resource is defined as "anything that has identity".

The requirement that an MPEG-21 Digital Item Identifier be a URI is also consistent with the statement that the MPEG-21 identifier may be a Uniform Resource Locator (URL). The term URL refers to a specific subset of URI that is in use today as pointers to information on the Internet; it allows for long-term to short-term persistence depending on the business case.

15) Identifying Digital Items

ISO/IEC-21000-3 allows any identifier in the form of a URI to be used as identifiers for Digital Items (and parts thereof). The specification also provides the ability the register identification systems through the process of a Registration Authority. Requirements for this Registration Authority are available in an Annex to the specification and ISO is in the process of appointing this Registration Authority. The Figure below shows how a music album – and its parts can be identified through DII.

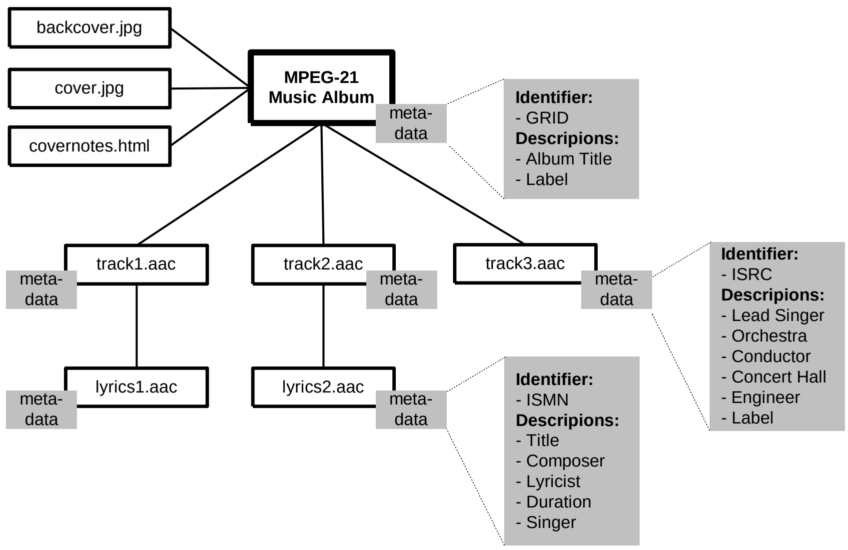

Figure 3 – Example: Metadata and Identifiers within an MPEG-21 Music Album

In some cases, it may be necessary to use an automated resolution[19] system to retrieve the Digital Item (or parts thereof) or information related to a Digital Item from a server (e.g., in the case of an interactive on-line content delivery system). An

[19] The act of submitting an identifier to a network service and receiving in return one or more pieces of some information (which includes resources, descriptions, another identifier, Digital Item, etc.) related to the identifier

example of such a resolution system can be found in an informative annex to the specification.

16) Identifying different Description Schemes

As different Users of MPEG-21 may have different schemes to describe "their" content, it is necessary for MPEG-21 DII to allow differentiating such different schemes. MPEG-21 DII utilises the XML mechanism of namespaces to do this.

17) Identifying different Types of Digital Items

Different parts of MPEG-21 will define different types of Digital Item. For example, Digital Item Adaptation (DIA) defines a "Context Digital Item" (XDI) in addition to the "Content Digital Item" (CDI). While CDIs contain resources such as MP3 files or MPEG-2 Video streams, XDIs contain information on the context in which a CDI will be used (more information in XDIs can be found in the section on DIA below).

DII provides a mechanism to allow an MPEG-21 Terminal to distinguish between these different Digital Item Types by placing a URI inside a Type tag as the sole child element of a Statement that shall appear as a child element of a Descriptor that shall appear as a child element of an Item. The syntax of the tag will be defined by subsequent parts of MPEG-21. If no such Type tag is present, the Digital Item is deemed to be a Content Digital Item.

MPEG-21 Part 4 – Intellectual Property Management and Protection (IPMP)

The 4th part of MPEG-21 will define an interoperable framework for Intellectual Property Management and Protection (IPMP). Fairly soon after MPEG-4, with its IPMP hooks, became an International Standard, concerns were voiced within MPEG that many similar devices and players might be built by different manufacturers, all MPEG-4, but many of them not interworking. This is why MPEG decided to start a new project on more interoperable IPMP systems and tools. The project includes standardized ways of retrieving IPMP tools from remote locations, exchanging messages between IPMP tools and between these tools and the terminal. It also addresses authentication of IPMP tools, and has provisions for integrating Rights Expressions according to the Rights Data Dictionary and the Rights Expression Language.

Efforts are currently ongoing to define the requirements for the management and protection of intellectual property in the various parts of the MPEG-21 standard currently under development.

MPEG-21 Part 5 – Rights Expression Language

Following an extensive requirements gathering process, which started in January 2001, MPEG issued a Call for Proposals during its July meeting in Sydney for a Rights Data Dictionary and a Rights Expression Language. Responses to this Call were processed during the December meeting in Pattaya and the evaluation process established an approach for going forward with the development of a specification, expected to be an International Standard in late 2003.

A Rights Expression Language is seen as a machine-readable language that can declare rights and permissions using the terms as defined in the Rights Data Dictionary.

The REL is intended to provide flexible, interoperable mechanisms to support transparent and augmented use of digital resources in publishing, distributing, and consuming of digital movies, digital music, electronic books, broadcasting, interactive games, computer software and other creations in digital form, in a way that protects digital content and honours the rights, conditions, and fees specified for digital contents. It is also intended to support specification of access and use controls for digital content in cases where financial exchange is not part of the terms of use, and to support exchange of sensitive or private digital content.

The Rights Expression Language is also intended to provide a flexible interoperable mechanism to ensure personal data is processed in accordance with individual rights and to meet the requirement for Users to be able to express their rights and interests in a way that addresses issues of privacy and use of personal data.

A standard Rights Expression Language should be able to support guaranteed end-to-end interoperability, consistency and reliability between different systems and services. To do so, it must offer richness and extensibility in declaring rights, conditions and obligations, ease and persistence in identifying and associating these with digital contents, and flexibility in supporting multiple usage/business models.

18) MPEG REL Data model

MPEG REL adopts a simple and extensible data model for many of its key concepts and elements.

The MPEG REL data model for a rights expression consists of four basic entities and the relationship among those entities. This basic relationship is defined by the MPEG REL assertion “grant”. Structurally, an MPEG REL grant consists of the following:

- The principal to whom the grant is issued
- The right that the grant specifies
- The resource to which the right in the grant applies
- The condition that must be met before the right can be exercised

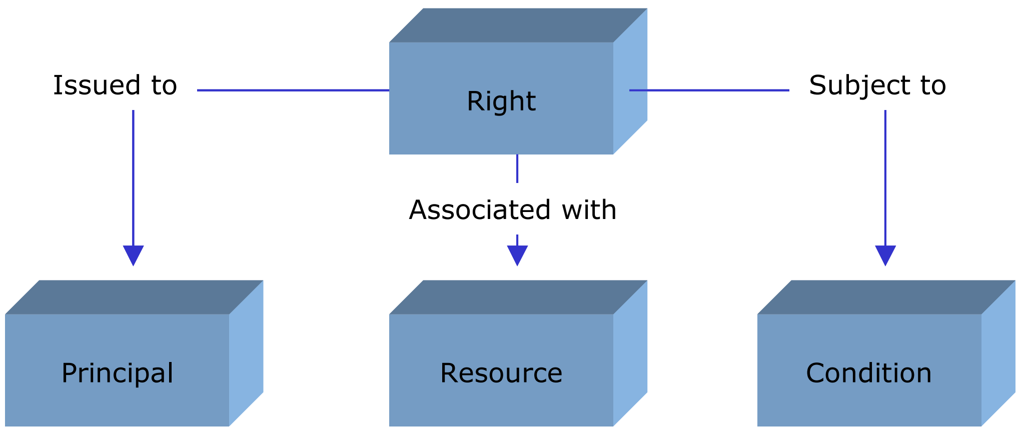

Figure 4 – The REL Data Model

19) Principal

A principal encapsulates the identification of principals to whom rights are granted. Each principal identifies exactly one party. In contrast, a set of principals, such as the universe of everyone, is not a principal.

A principal denotes the party that it identifies by information unique to that individual. Usefully, this is information that has some associated authentication mechanism by which the principal can prove its identity. The Principal type supports the following identification technologies:

- A principal that must present multiple credentials, all of which must be simultaneously valid, to be authenticated.

- A keyHolder, meaning someone identified as possessing a secret key such as the private key of a public / private key pair.

- Other identification technologies that may be invented by others.

20) Right

A right is the "verb" that a principal can be granted to exercise against some resource under some condition. Typically, a right specifies an action (or activity) or a class of actions that a principal may perform on or using the associated resource.

MPEG REL provides a right element to encapsulate information about rights and provides a set of commonly used, specific rights, notably rights relating to other rights, such as issue, revoke and obtain. Extensions to MPEG REL could define rights appropriate to using specific types of resource. For instance, the MPEG REL content extension defines rights appropriate to using digital works (e.g., play and print).

21) Resource

A resource is the "object" to which a principal can be granted a right. A resource can be a digital work (such as an e-book, an audio or video file, or an image), a service (such as an email service, or B2B transaction service), or even a piece of information that can be owned by a principal (such as a name or an email address).

MPEG REL provides mechanisms to encapsulate the information necessary to identify and use a particular resource or resources that match a certain pattern. The latter allows identification of a collection of resources with some common characteristics. Extensions to MPEG REL could define resources appropriate to specific business models and technical applications.

22) Condition

A condition specifies the terms, conditions and obligations under which rights can be exercised. A simple condition is a time interval within which a right can be exercised. A slightly complicated condition is to require the existence of a valid, prerequisite right that has been issued to some principal. Using this mechanism, the eligibility to exercise one right can become dependent on the eligibility to exercise other rights.

MPEG REL defines a condition element to encapsulate information about conditions and some very basic conditions. Extensions to MPEG REL could define conditions appropriate to specific distribution and usage models. For instance, the MPEG REL content extension defines conditions appropriate to using digital works (e.g., watermark, destination, and renderer).

23) Relationship with MPEG Terminology

The entities in the MPEG REL data model: "principal", "right", "resource", and "condition", can correspond to (but are not necessarily equivalent to) to "user" including "terminal", "right", "digital item" and "condition" in the MPEG-21 terminology.

24) Encapsulated in XML Schema

Since MPEG REL is defined using the XML Schema recommendation from W3C, its element model follows the standard one that relates its elements to other classes of elements. For example, the "grant" element is related to its child elements, "principal", "right", "resource" and "condition".

MPEG-21 Part 6 – Rights Data Dictionary

Following the evaluation of submissions in response to a Call for Proposals the specification of a Rights Data Dictionary (RDD) began in December 2001. The working draft was refined at the following three meetings and a Committee Draft published in July 2002. The following points summarise the scope of this specification:

The Rights Data Dictionary (RDD) comprises a set of clear, consistent, structured, integrated and uniquely identified Terms to support the MPEG-21 Rights Expression Language.

The structure of the dictionary is specified, along with a methodology for creating the dictionary. The means by which further Terms may be defined is also explained.

The Dictionary is a prescriptive Dictionary, in the sense that it defines a single meaning for a Term represented by a particular RDD name (or Headword), but it is also inclusive in that it recognizes the prescription of other Headwords and definitions by other Authorities and incorporates them through mappings. The RDD also supports the circumstance that the same name may have different meanings under different Authorities. The RDD specification has audit provisions so that additions, amendments and deletions to Terms and their attributes can be tracked.

RDD recognises legal definitions as and only as Terms from other Authorities that can be mapped into the RDD. Therefore Terms that are directly authorized by RDD neither define nor prescribe intellectual property rights or other legal entities.

As well as providing definitions of Terms for use in the REL, the RDD specification is designed to support the mapping and transformation of metadata from the terminology of one namespace (or Authority) into that of another namespace (or Authority) in an automated or partially-automated way, with the minimum ambiguity or loss of semantic integrity.

The dictionary is based on a logical model, the Context Model, which is the basis of the dictionary ontology. The model is described in detail in the specification. It is based on the use of verbs which are contextualised so that a dictionary created with it can be as extensible and granular are required.

MPEG-21 Part 7 - Digital Item Adaptation

The goal of the Terminals and Networks key element is to achieve interoperable transparent access to (distributed) advanced multimedia content by shielding users from network and terminal installation, management and implementation issues. This will enable the provision of network and terminal resources on demand to form user communities where multimedia content can be created and shared, always with the agreed/contracted quality, reliability and flexibility, allowing the multimedia applications to connect diverse sets of Users, such that the quality of the user experience will be guaranteed.

Towards this goal the adaptation of Digital Items is required. As shown in this conceptual architecture, a Digital Item is subject to a resource adaptation engine, as well as a descriptor adaptation engine, which produce together the adapted Digital Item.

It is important to emphasise that the adaptation engines themselves are non-normative tools of Digital Item Adaptation. However, descriptions and format-independent mechanisms that provide support for Digital Item Adaptation in terms of resource adaptation, descriptor adaptation, and/or Quality of Service management are within the scope of the requirements.

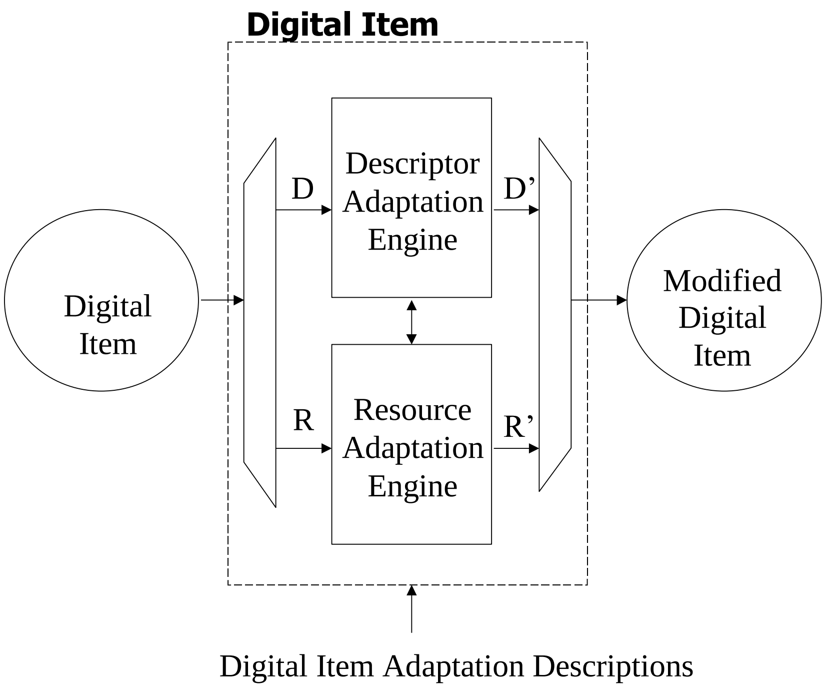

Figure 5 – Concept of Digital Item Adaptation

In May 2002, a number of responses to the Call for Proposals on MPEG-21 Digital Item Adaptation were received. Based on the evaluation of these proposals, a Working Draft has been produced. The specific items targeted for standardization are outlined below.

- User Characteristics: Description tools that specify the characteristics of a User, including preferences to particular media resources, preferences regarding the presentation of media resources, and the mobility characteristics of a User. Additionally, description tools to support the accessibility of Digital Items to various users, including those with audio-visual impairments, are being considered.

- Terminal Capabilities: Description tools that specify the capability of terminals, including media resource encoding and decoding capability, hardware, software and system-related specifications, as well as communication protocols that are supported by the terminal.
- Network Characteristics: Description tools that specify the capabilities and conditions of a network, including bandwidth utilization, delay and error characteristics.
- Natural Environment Characteristics: Description tools that specify the location and time of a User in a given environment, as well as audio-visual characteristics of the natural environment, which may include auditory noise levels and illumination properties.
- Resource Adaptability: Tools to assist with the adaptation of resources including the adaptation of binary resources in a generic way and metadata adaptation. Additionally, tools that assist in making resource-complexity trade-offs and making associations between descriptions and resource characteristics for Quality of Service are targeted.
- Session Mobility: Tools that specify how to transfer the state of Digital Items from one User to another. Specifically, the capture, transfer and reconstruction of state information will be specified.

MPEG-21 Part 8 – Reference Software

The part of MPEG-21 that has most recently been identified as a candidate for specification is Reference Software. Reference software will form the first of what is envisaged to be a number of systems-related specifications in MPEG-21. Other candidates for specification are likely to include a binary representation of the Digital Item Declaration and an MPEG-21 file format.

The development of the Reference Software will be based on the requirements that have been defined for an architecture for processing Digital Items.

MPEG-21 Part 9 – File Format

An MPEG-21 Digital Item can be a complex collection of information. Both still and dynamic media (e.g. images and movies) can be included, as well as Digital Item information, meta-data, layout information, and so on. It can include both textual data (e.g. XML) and binary data (e.g. an MPEG-4 presentation or a still picture). For this reason, the MPEG-21 file format will inherit several concepts from MP4, in order to make ‘multi-purpose’ files possible. A dual-purpose MP4 and MP21 file, for example, would play just the MPEG-4 data on an MP4 player, and would play the MPEG-21 data on an MP21 player.

Requirements have been established with respect to the file format and work on the WD has been initiated.

Proposals and Recommendations for Further Work

The following recommendations for WG11 standardisation activities with respect to the MPEG-21 multimedia framework are proposed:

Persistent Association of Identification and Description with Digital Items

As a logical extension to the ongoing specification of the Digital Item Declaration and Digital Item Identification, MPEG intends to consider the requirements for the persistent association of identification and description with content. MPEG experts wish to define the functional requirements for the persistent association of identification and description with content and how this interacts with the rest of the MPEG-21 architecture.

The term **persistent association** is used to categorise all the techniques for managing identification and description with content[20]. This will include the carriage of identifiers within the context of different content file and transport formats, including file headers and embedded into content as a watermark. It also encompasses the ability for identifiers associated with content to be protected against their unauthorised removal and modification.

The Technical Report documents the following high-level requirements for persistent association of identification and description with Digital Items:

1. A framework that supports Digital Item identification and description shall make it possible to persistently associate identifiers and descriptors with media resources. This includes that the association of media resources with identifiers and/or descriptors may need to be authenticated;

2. The environment for the storage of identifiers and descriptions associated with Digital Items shall fulfil the following requirements in a standardised way:

    a. It shall be possible that descriptors contain binary and/or textual information; (e.g., HTML, AAC, JPEG, etc);

[20] The term ‘content’ is widely used by many industries that apply various meanings. In the current specifications of MPEG-21 the term ‘content’ has therefore been replaced by ‘Resource’ (for a definition see section [51]11)).

b. It shall be possible to associate descriptors with those elements within a hierarchical Digital Item that contain Resources;

c. It shall be possible to store, within the Digital Item, a reference to descriptive metadata regardless of its location;

3. A framework that supports Digital Item identification and description shall allow for locating Digital Items from its descriptions and vice versa. Note that this does not necessarily imply that they are bundled together;

4. A framework that supports Digital Item identification and description shall provide an efficient resolution system for related Digital Items, such as different versions, different manifestations of the same Digital Item, different names of the same Digital Item (e.g. aliases, nick names), their elements, etc.;

5. A framework that supports Digital Item identification and description should provide, provide for, support, adopt, reference or integrate mechanisms to define levels of access to descriptions within the rights expressions, such as the discovery of usage rules[21].

Subsequent to the completion of the Technical Report a new activity called Digital Item Adaptation[22] has commenced (see section 0). A high-level requirement for persistent association related to Digital Item Adaptation is as follows:

6. **Digital Item Adaptation** has been identified as one essential aspect of Terminals and Networks that will provide tools to support resource adaptation, descriptor ('metadata') adaptation, and Quality of Service management. As part of this work item, a description of usage environments, including terminal and network characteristics, as well as information describing user preferences is required. A

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[21] More information can be found in the RDD and REL Working Draft specifications (that will become Parts 5 and 6 that are attached to this Call for Requirements.

[22] Digital Item Adaptation is the subject of a Call for Proposals which is attached for information to this CfR.

requirement exists for the persistent association of such descriptions to Digital Items and their Resources.

While MPEG has identified the need for such persistent association of identification and description, the requirements are not yet well enough understood to decide what MPEG might consider necessary to standardise. Hence, MPEG is now asking interested parties and experts to submit requirements for this technology to MPEG, and invites these parties and experts to take part in the work.

MPEG seeks these inputs by its 61^{st} meeting, in July 2002. It will be used by MPEG to plan future work in assessing the ability of existing specifications (of both MPEG and others) to meet these requirements and in planning future specification. Further timing will be decided when the requirements are better understood.

Content Representation

The goal of the ‘Content Representation’ item has as its goal to provide, adopt or integrate content representation technologies able to efficiently represent MPEG-21 content, in a scalable and error resilient way. The content representation of the media resources shall be synchronisable and multiplexed and allow interaction.

The encoding of XML defined by the MPEG-7 specification part 1 will be extended to fulfil this requirement. The call for contributions for these extensions is defined in N4715 under the item " Binary representation of MPEG-21 Digital Item Declaration".

This item should allow the Multimedia Framework to optimally use existing and ongoing developments of media coders in MPEG.

Event Reporting

MPEG-21 Event Reporting should standardise metrics and interfaces for performance of all reportable events in MPEG-21 and provide a means of capturing and containing these metrics and interfaces that refers to identified Digital Items, environments, processes, transactions and Users.

Such metrics and interfaces will enable Users to understand precisely the performance of all reportable events within the framework. “Event Reporting” must provide Users a means of acting on specific interactions, as well as enabling a vast set of out-of-scope processes, frameworks and models to interoperate with MPEG-21.

Timetable for MPEG-21 Standardisation

The following table sets out the current timetable for MPEG-21 standardisation.

Also consult: http://www.itscj.ipsj.or.jp/sc29/29w42911.htm#MPEG-21.

MPEG-21<A> (Multimedia framework (MPEG-21))										
Project No.	Reference		Title	Stage (ballot due date)	Target Dates					Project Editor (RA: Registration Authority) (*: to be appointed)
					WD	CD PDAM PDTR	DIS DAM DCOR	FDIS FDAM	IS AMD TR COR	
JTC 1.29.17.11 (TR 21000-1)	ISO/IEC TR 21000-1:2004 (DTRSC 29 N 6149)		Part 1: Vision, Technologies and Strategy	TR	Published (2004-11-01) 2nd edition					• ™Dr. Jan Bormans • ™Mr. Niels Rump
JTC 1.29.17.12 (21000-2)	ISO/IEC 21000-2:2005 (FDIS: SC 29 N 6715)		Part 2: Digital Item Declaration	IS	Published (2005-10-01) 2nd edition					• ™Dr. Ian S Burnett □ ™Mr. Gerrard Drury □ ™Dr. Frederik De Keukelaere □ ™Dr. Rik Van de Walle
JTC 1.29.17.12.01 (21000-2/AMD1)	ISO/IEC 21000-2:2005/Amd.1:2012 (FDAM: SC 29 N 12367)		Part 2: Digital Item Declaration AMENDMENT 1: Presentation of digital item	AMD	Published (2012-03-15)					Mr. Filippo Chiariglione Dr. Tiejun Huang Dr. Jihun Cha
JTC 1.29.17.03 (21000-3)	ISO/IEC 21000-3:2003 (FDIS: SC 29 N 5002)		Part 3: Digital Item Identification	IS	Published (2003-04-01)					• ™Mr. Niels Rump □ ™Dr.

						Young-Won Song □™Dr. Hideki Sakamoto RA: CISAC
JTC 1.29.17.03.01 (21000-3/AMD1)	ISO/IEC 21000-3:2003/Amd.1:2007 (SC 29 N 7722)		Part 3: Digital Item Identification AMENDMENT 1: Related identifier types	AMD	Published (2007-02-01)	• ™Dr. Jeroen Bekaert □™Mr. Niels Rump
JTC 1.29.17.03.02 (21000-3/AMD2)	ISO/IEC 21000-3:2003/Amd.2:2013 (FDIS: SC 29 N 12736)		Part 3: Digital Item Identification AMENDMENT 2: Digital item semantic relationships	AMD	Published (2013-07-15)	• ™Dr. Maria Teresa Andrade • ™Mr. Helder Castro • ™Mr. Angelo Difino • ™Mr. Nicola Blefari Melazzi • ™Mr. Giuseppe Tropea
JTC 1.29.17.04 (21000-4)	ISO/IEC 21000-4:2006 (FDIS: SC 29 N 7122)		Part 4: Intellectual Property Management and Protection Intellectual Property Management and	IS	Published (2006-04-01)	• ™Mr. Zhongyang Huang □™Mr. Shane Lauf

			Protection Components			• ™Dr. Eva Rodriguez □ ™Mr. Simon Watt
JTC 1.29.17.04/COR1 (21000-4/COR1)	ISO/IEC 21000-4:2006/Cor.1:2012 (SC 29 N 12507)		Part 4: Intellectual Property Management and Protection Components TECHNICAL CORRIGENDUM 1	COR	Published (2012-03-15)	
JTC 1.29.17.04.01 (21000-4/AMD1)	ISO/IEC 21000-4:2006/Amd.1:2007 (FDAM: SC 29 N 8529)		Part 4: Intellectual Property Management and Protection Components AMENDMENT 1: IPMP components base profile	AMD	Published (2007-12-01)	• ™Hendry □ ™Dr. Takafumi Ueno
JTC 1.29.17.04.02 (21000-4/AMD2)	ISO/IEC 21000-4:2006/Amd.2:2012 (FDAM: SC 29 N 12368)		Part 4: Intellectual Property Management and Protection Components AMENDMENT 2: Protection of presentation element	AMD	Published (2012-04-01)	Mr. Filippo Chiariglione Dr. Tiejun Huang
JTC 1.29.17.05 (21000-5)	ISO/IEC 21000-5:2004 (FDIS: SC 29 N 5543)		Part 5: Rights Expression Language	IS	Published (2004-04-01)	• ™Mr. Thomas DeMartini □ ™Mr. M Paramasivam □ ™Dr. Xin

						Wang □™Mr. Barney Wragg
JTC 1.29.17.05.01 (21000-5/AMD1)	ISO/IEC 21000-5:2004/Amd.1:2007 (FDAM: SC 29 N 7763)		Part 5: Rights Expression Language AMENDMENT 1: MPEG-21 REL profilesMAM (Mobile And optical Media) profile	AMD	Published (2007-02-01)	• ™Mr. Chris Barlas □™Dr. Jaime Delgado □™Dr. Xin Wang
JTC 1.29.17.05.02 (21000-5/AMD2)	ISO/IEC 21000-5:2004/Amd.2:2007 (FDAM: SC 29 N 8288)		Part 5: Rights Expression Language AMENDMENT 2: MPEG-21 REL profiles - the DAC profile	AMD	Published (2007-09-15)	• ™Mr. Filippo Chiariglione □™Mr. Taehyun Kim □™Dr. Xin Wang
JTC 1.29.17.05.03 (21000-5/AMD3)	ISO/IEC 21000-5:2004/Amd.3:2008 (FDAM: SC 29 N 9221)		Part 5: Rights Expression Language AMENDMENT 3: ORC (Open Release Content) OAC (Open Access Content) profile	AMD	Published (2008-07-15)	• ™Mr. Chris Barlas □™Dr. Jaime Delgado □™Mr. Taehyun Kim □™Mr. Florian Schreiner □™Dr. Xin

						Wang
JTC 1.29.17.06 (21000-6)	ISO/IEC 21000-6:2004 (FDIS: SC 29 N 5551)		Part 6: Rights Data Dictionary	IS	Published (2004-05-15)	• ™Mr. Chris Barlas □ ™Mr. Godfrey Rust RA: International DOI Foundation (IDF)
JTC 1.29.17.06/COR1 (21000-6/COR1)	ISO/IEC 21000-6:2004/Cor.1:2005 (SC 29 N 6498)		Part 6: Rights Data Dictionary TECHNICAL CORRIGENDUM 1	COR	Published (2005-03-01)	
JTC 1.29.17.06/COR2 (21000-6/COR2)	ISO/IEC 21000-6:2004/Cor.2:2007 (SC 29 N 7959)		Part 6: Rights Data Dictionary TECHNICAL CORRIGENDUM 2	COR	Published (2007-02-01)	
JTC 1.29.17.06.01 (21000-6/AMD1)	ISO/IEC 21000-6:2004/Amd.1:2006 (FDAM: SC 29 N 7724)		Part 6: Rights Data Dictionary AMENDMENT 1: Digital Item Identifier relationship types	AMD	Published (2006-12-15)	• ™Dr. Jeroen Bekaert □ ™Mr. Niels Rump
JTC 1.29.17.107 (21000-7)	ISO/IEC 21000-7:2007 (SC 29 N 8584)		Part 7: Digital Item Adaptation	IS	Published (2007-12-15) 2nd edition (consolidation of 1st/Amds 1, 2 and Cor 1)	• ™Mr. Sylvain Devillers □ ™Dr. Michael Ransburg

						• ™Dr. Christian Timmerer
JTC 1.29.17.107/COR1 (21000-7/COR1)	ISO/IEC 21000-7:2007/Cor.1:2008 (SC 29 N 9871)		Part 7: Digital Item Adaptation TECHNICAL CORRIGENDUM 1	COR	Published (2008-12-15)	
JTC 1.29.17.107.01 (21000-7/AMD1)	ISO/IEC 21000-7:2007/Amd.1:2008 (FDAM: SC 29 N 9558)		Part 7: Digital Item Adaptation AMENDMENT 1: Query format capabilities	AMD	Published (2008-12-15)	• ™Dr. Chistian Timmerer
JTC 1.29.17.108 (21000-8)	ISO/IEC 21000-8:2008 (FDIS: SC 29 N 8717)	Reference Software	Part 8: Reference Software	IS	Published (2008-03-01) 2nd edition	• ™Dr. Saar De Zutter ™Dr. Frederik De Keukelaere ™Mr. Gerrard Drury ™Dr. Chistian Timmerer ™Dr. Xin Wang
JTC 1.29.17.108.01 (21000-8/AMD1)	ISO/IEC 21000-8:2008/Amd.1:2009 (FDAM: SC 29 N 9890)	Reference Software	Part 8: Reference Software AMENDMENT 1: Extra reference software	AMD	Published (2009-04-01)	• ™Dr. Saar De Zutter • ™Mr. Florian Schreiner

JTC 1.29.17.108.02 (21000-8/AMD2)	ISO/IEC 21000-8:2008/Amd.2:2011 (SC 29 N 12261)	Reference Software	Part 8: Reference Software AMENDMENT 2: Reference software for Media Value Chain Ontology	AMD	Published (2011-11-01)	Dr. Jaime Delgado Mr. Victor Rodriguez Doncel
JTC 1.29.17.108.03 (21000-8/AMD3)	ISO/IEC 21000-8:2008/Amd.3:2015 (SC 29 N 14432)		Part 8: Reference Software AMENDMENT 3: Contract Expression Language (CEL) and Media Contract Ontology (MCO) Reference Software	AMD	Published (2015-04-01)	• ™Laurent Boch • ™Dr. Jaime Delgado
JTC 1.29.17.09 (21000-9)	ISO/IEC 21000-9:2005 (FDIS: SC 29 N 6501)		Part 9: File Format	IS	Published (2005-07-01)	• ™Mr. David Singer
JTC 1.29.17.09.01 (21000-9/AMD1)	ISO/IEC 21000-9:2005/Amd.1:2008 (FDAM: SC 29 N 9465)	Annex D of ISO/IEC 21000-9:2005	Part 9: File Format AMENDMENT 1: MIME type registration	AMD	Published (2008-10-01)	• ™Mr. David Singer □™Dr. Christian Timmerer
JTC 1.29.17.010 (21000-10)	ISO/IEC 21000-10:2006 (FDIS: SC 29 N 6828)		Part 10: Digital Item Processing	IS	Published (2006-01-01)	• ™Dr. Jeroen Bekaert □™Dr. Ian S Burnett □™Dr.

						Frederik De Keukelaere □™Mr. Gerrard Drury □™Dr. Munchurl Kim □™Dr. Viswanathan Swaminathan □™Dr. Rik Van de Walle
JTC 1.29.17.010.01 (21000-10/AMD1)	ISO/IEC 21000-10:2006/Amd.1:2006 (FDAM: SC 29 N 7725)		Part 10: Digital Item Processing AMENDMENT 1: Additional C++ bindings	AMD	Published (2006-12-15)	• ™Dr. Frederik De Keukelaere • ™Dr. Saar De Zutter
JTC 1.29.17.011 (TR 21000-11)	ISO/IEC TR 21000-11:2004 (TR: SC 29 N 6151)		Part 11: Evaluation Methods for Persistent Association Technologies	TR	Published (2004-11-15)	• ™Mr. Richard Gooch □™Mr. Paul Jessop □™Mr. Niels Rump
JTC 1.29.17.012 (TR 21000-12)	ISO/IEC TR 21000-12:2005 (TR: SC 29 N 6449)		Part 12: Test Bed for MPEG-21 Resource Delivery	TR	Published (2005-04-01)	• ™Mr. Chun-Jen Tsai □™Prof. Mihaela van

						der Schaar
JTC 1.29.17.013 (21000-13) re-numbered to JTC 1.29.13.210.01 (14496-10/AMD1)			Part 13: Scalable Video Coding	-	-	-
JTC 1.29.17.014 (21000-14)	ISO/IEC 21000-14:2007 (FDIS: SC 29 N 8570)	Conformance Bitstreams	Part 14: Conformance Testing	IS	Published (2007-12-15)	• ™Mr. Sylvain Devillers □™Mr. Thomas DeMartini □™Dr. Andrew Tokmakoff □™Dr. Saar De Zutter
JTC 1.29.17.015 (21000-15)	ISO/IEC 21000-15:2006 (FDIS: SC 29 N 7289)		Part 15: Event Reporting	IS	Published (2006-07-15)	• ™Ms. Kyunghee Ji □™Mr. Thomas Kummer-Hardt □™Mr. Francois-Xavier Nuttall □™Mr. Niels Rump □™Ms. Young-Joo Song □™Dr.

						Andrew Tokmakoff
JTC 1.29.17.015/COR1 (21000-15/COR1)	ISO/IEC 21000-15:2006/Cor.1:2008 (SC 29 N 8964)		Part 15: Event Reporting TECHNICAL CORRIGENDUM 1	COR	Published (2008-02-01)	• ™Dr. Jaime Delgado □ ™Dr. Christian Timmerer
JTC 1.29.17.015.01 (21000-15/AMD1)	ISO/IEC 21000-15:2006/Amd.1:2008 (FDAM: SC 29 N 9466)		Part 15: Event Reporting AMENDMENT 1: Security in Event Reporting	AMD	Published (2008-10-01)	• ™Dr. Jaime Delgado • ™Dr. Eva Rodriguez
JTC 1.29.17.016 (21000-16)	ISO/IEC 21000-16:2005 (FDIS:SC 29 N 6753)		Part 16: Binary Format	IS	Published (2005-10-15)	• ™Mr. Claude Seyrat
JTC 1.29.17.017 (21000-17)	ISO/IEC 21000-17:2006 (FDIS: SC 29 N 7297)		Part 17: Fragment Identification for MPEG Media Types Fragment Identification of MPEG Resources	IS	Published (2006-09-15)	• ™Dr. Myriam Amielh • ™Mr. Sylvain Devillers
JTC 1.29.17.018 (21000-18)	ISO/IEC 21000-18:2007 (FDIS: SC 29 N 8084)		Part 18: Digital Item Streaming	IS	Published (2007-06-15)	• ™Mr. Gerrard Drury □ ™Mr. Joseph Thomas-Kerr RA: CISAC*

JTC 1.29.17.018.01 (21000-18/AMD1)	ISO/IEC 21000-18:2007/Amd.1:2008 (FDAM: SC 29 N 8979)		Part 18: Digital Item Streaming AMENDMENT 1: Simple fragmentation rule	AMD	Published (2008-06-01)	• ™Mr. Peder Drege □™Mr. Gerrard Drury □™Mr. Joseph Thomas-Kerr □™Mr. Thomas Skjolberg
JTC 1.29.17.019 (21000-19)	ISO/IEC 21000-19:2010 (FDIS: SC 29 N 11041)		Part 19: Media Value Chain Ontology	IS	Published (2010-06-15)	• ™Dr. Miran Choi • ™Dr. Jaime Delgado • ™Mr. Marc Gauvin • ™Mr. Victor Rodriguez Doncel
JTC 1.29.17.019.00..00.02(21000-19/AMD1)	ISO/IEC 21000-19:2010/PDAM 1 [SC 29 N 16024]		Part 19: Media Value Chain Ontology -- Amendment 1: Extensions on time-segments and multi-track audio	PDAM (2016-09-23)	2016-06 2016-10 2017-04 2017-07	Thomas Wilmering Panos Kudumakis
JTC 1.29.17.020 (21000-20)	ISO/IEC 21000-20:2013 (FDIS: SC 29 N 13189)		Part 20: Contract Expression Language	IS	Published (2013-07-01)	• ™Dr. Jaime

						Delgado • ™Mr. Francesco Gallo • ™Mr. Victor Rodriguez Doncel • ™Dr. Xin Wang
JTC 1.29.17.120 (21000-20)	ISO/IEC 21000-20:201x [2nd Edition] (SC 29 N 16044)		Part 20: Contract Expression Language	IS	To be published (Proof due: 2016-10-19)	Dr. Jaime Delgado Laurent Boch Silvia Llorente
JTC 1.29.17.021 (21000-21)	ISO/IEC 21000-21:2013 (FDIS: SC 29 N 13331)		Part 21: Media Contract Ontology	IS	Published (2013-07-01)	• ™Dr. Jaime Delgado Laurent Boch ™Dr. Xin Wang
JTC 1.29.17.021/COR1 (21000-21/COR1)	ISO/IEC 21000-21:2013/Cor.1 (SC 29 N 14364)		Part 21: Media Contract Ontology TECHNICAL CORRIGENDUM 1	COR	Published (2015-04-01)	
JTC 1.29.17.121 (21000-21)	ISO/IEC 21000-21:2016 [2nd Edition] (SC 29 N 15929)		Part 21: Media contract ontology	IS	To be published (two weeks review due: 2016-10-15	Dr. Jaime Delgado Laurent Boch
JTC 1.29.17.022 (21000-	ISO/IEC 21000-22:2016		Part 22: User	IS	To be published	Bojan

22)	(SC 29 N 15931)		Description							Joveski Si-Hwan Jang Alberto Messina Sabino Metta Sanghyun Joo
JTC 1.29.17.022.01 (21000-22/AMD1)	ISO/IEC 21000-22:201x/DAM 1.2 (SC 29 N 15986)		Part 22: User Description, AMENDMENT 1: Reference Software for MPEG-21 User Description	DAM (2016-11-24)	-	2016-02	2016-06	2017-02		Bojan Joveski Si-Hwan Jang Alberto Messina Sabino Metta Sanghyun Joo